METALLURGIA

The British Journal of Metals

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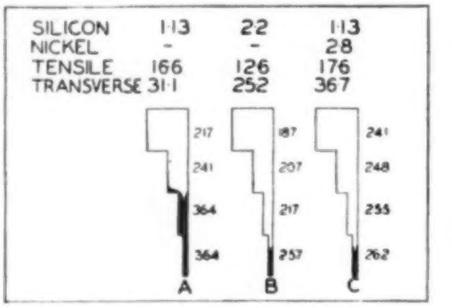
SHORT TALKS ON NICKEL CAST IRONS

No. I

Improving Ordinary Engineering Castings

The cheapness of cast iron and the ease with which it can be cast have combined to maintain its position as one of the basic materials of engineering construction, in spite of its comparative weakness. In recent years, however, its usefulness and importance have been greatly increased by the improvements in its properties which have resulted from suitable alloy additions, especially that of nickel.

Uniformity of Product.—By graphitising the iron, nickel prevents chill and hard spots. On the other hand, unlike silicon and other additions which also prevent chill, nickel has a densifying effect on the pearlitic structure of the thicker sections. It thus eliminates the wide range of structures which normally result from the different cooling rates of various parts.



Comparison of Silicon and Nickel Cast Irons. Tensile Strength in tons per sq. in. Transverse Strength in Modulus of Rupture, tons per sq. in.

These effects are summarised in the diagram. Section A represents an ordinary cast iron, the chilled portions being shown in a solid block. In Section B silicon has been added to decrease chill but there is considerable loss of hardness in the thicker portions. In C, to which nickel has been added, the reduction of chill is accompanied by an increase of hardness.

Pressure Tightness.—In many castings, where large or lumpy masses are associated with thin sections, porosity is likely to occur. Frequently this trouble is deep-seated and is not revealed until the application of a pressure test after machining. The foundryman's difficulty is frequently increased by the necessity for machining thin sections, since, while reduction of silicon will make the thick parts sounder, chill spots on the thin sections will spoil machinability. The addition of 1·5% of nickel will overcome the trouble and give castings which are dense in the heavy sections and readily machinable in all light sections.

Density.—Nickel additions to irons in which the silicon content is controlled result in improvements not only in strength and hardness, but also in all properties which depend on density and uniformity, such as wearing quality and fineness of finish. The uniformity of the metal eliminates casting strains and renders any long ageing treatment unnecessary. Improved density further cheapens production by enabling the foundryman to minimise or eliminate chills and denseners.

Machinable Hardness.—Castings which possess abnormally high hardness and are yet commercially machinable can be produced in light cast irons containing about 2 to 3% of nickel. The structure of such castings is very uniform, since the use of nickel is especially valuable in preventing the formation of chilled spots. With hardness figures as high as 260 or 280 Brinell, machining can be carried out at speeds little short of normal.

Composition.—The composition of the iron apart from silicon and the special additions will naturally depend on the particular application. A good grade of base iron should be employed; phosphorus and sulphur should be below 0·5% and 0·12% respectively. Manganese should generally be on the high side at between 0·5 and 1%, while carbon should be controlled with silicon.

Control of the silicon is not always easy or even possible. An alternative is available in the use of combined nickel and chromium additions. The chromium serves to harden the iron, thus offsetting the silicon content. Nickel, as before, eliminates chill and adds further strength and density. Such additions are generally made in the proportion of three parts of nickel and one part of chromium, a common practice being the use of 1·5% of nickel and 0·5% of chromium.

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

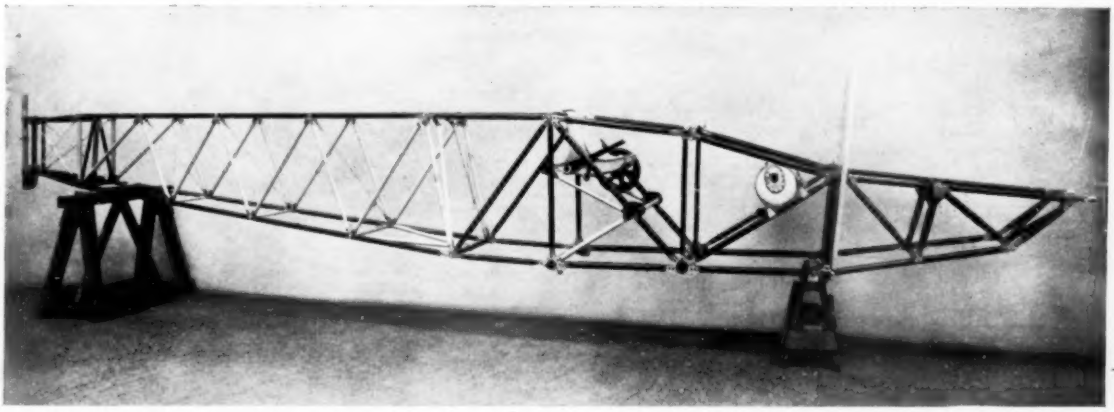
NOVEMBER, 1934. VOL. XI., No. 61.

Future Research on Alloy Steels

By Prof. J. H. Andrew, D.Sc.

Most of the revolutionary compositions of alloys on the market are due rather to methods of "hit and miss," and the object of the scientific metallurgist should be to substitute for this unsatisfactory method one, more certain and scientific, capable of producing the required article rapidly and in a more satisfactory manner. The author suggests that co-operative research, carried out by the various research institutions, is almost essential if progress is to be developed on correct and productive lines.

THE history of alloy steels and their present position have been dealt with by Professor Sir Harold C. H. Carpenter, F.R.S.,[1] and Professor D. Hanson, D.Sc.,[2] respectively, and there remains the future to be taken into account. Any consideration of a policy of research must necessarily be regarded as a conception of an individual. Whilst certain suggestions may not in themselves bear fruit, they may, by giving rise to new ideas in the minds of others, perform a useful function with respect to metallurgical work of the future.



By Courtesy of H. G. Hawker Eng. Co. Ltd.

Extensive use is made of nickel steel in the construction of the Hawker "Hart" fuselage.

In determining a future policy, many facts must be taken into consideration. In the first place, the present situation must be borne in mind in order to ascertain whether certain phenomena, now regarded as being adequately explained, may be viewed from a different standpoint. Up to the present much of the scientific research work has been confined to a determination of the equilibria of alloy systems—binary, ternary, and even more complex. It is unfortunate, however, that investigations concerned with equilibria rarely include measurements of the mechanical properties of the materials investigated, and it is largely upon the industry and certain research institutions that we have to depend for such tests—of great industrial importance. Metallurgical science is thus in a peculiar position of possessing data which in many cases are unconnected.

What is required is co-ordinated research, so arranged that every type of useful determination is carried out on the same series of alloys. Whilst equilibria are extremely useful as a guide to the theory of alloy systems, the uses of alloys depend almost entirely upon their mechanical properties and resistance to corrosion and to heat, and attempts should be made to connect directly the theory with practice.

Space Lattice Configuration.

When the X-ray study of alloy systems was in its infancy, it was expected that there would be some direct relation between metals crystallising in the same configuration and that similar forms would readily alloy one with another. In the same way, it might be argued that a metal crystallising in the body-centred form would, when added to iron, tend to retain this particular configuration, and similarly, a metal existing in the face-centred form would, when added to iron, tend to retain this particular configuration, and similarly, a metal existing in the face-centred form would tend to retain the iron in its gamma or face-centred state. It is now known, however, that the space lattice configuration of an element is no criterion of the effect it will produce when alloyed with iron. For instance, aluminium, which has a face-centred form, when added to iron in an amount of about 1 per cent., completely retains the alpha or body-centred form at all temperatures, and there are other instances in which the face-centred element will retain the body-centred lattice in iron, and *vice versa*. It is therefore evident that the property of the crystal is not the determining factor in the alloy system, and it is necessary to consider atomic properties before a solution to the problem of alloying can be arrived at.

[1] METALLURGIA, vol. 9, No. 54, pp. 175-8.
[2] METALLURGIA, vol. 10, No. 57, pp. 75-8.

The Effect of Metals which Retain Iron in its Alpha State.

Owing to the difficulty of making iron alloys entirely devoid of carbon, very little work has been carried out on the mechanical properties of the carbonless systems, but investigations carried out by the writer with many collaborators strongly suggest that metals which, when added to iron, retain or tend to retain, the alpha state, have but little beneficial effect upon mechanical properties, and many determinations have led to the belief that in such alloys carbon is the all-important element. As an example, it may be stated that alloys containing chromium along with molybdenum or tungsten in amounts sufficient to retain the alpha state at all temperatures, but insufficient to form a new phase, bring about little or no change in the tensile properties of pure iron. With a carbon content, in excess of 0·03%, however, a considerable improvement may be detected, owing to the displacement of the normal eutectoid composition by the added elements.

It is not suggested that such alpha irons have not their uses in industry; they may possess such useful properties as a high resistance to corrosion or to scaling at elevated temperatures. Further, one must not overlook the possibility of their retaining a strength at high temperatures considerably greater than pure iron.

Alloying Elements which Tend to Retain the Gamma State.

Of alloys which tend to retain the gamma state, the most important and effective are undoubtedly nickel and manganese. Sir Robert Hadfield has shown that in an alloy containing only a slight amount of carbon with manganese in the neighbourhood of 5% gives the maximum stress value for the system. On the other hand, he has shown that 12% of nickel gives an even higher maximum stress in a relatively carbonless alloy. In both these alloys the transformation from gamma to alpha occurs at a temperature lower than that in pure iron.

It is apparent from what has been said that in a carbonless alloy the only elements which will produce an improvement in the tensile properties are those which depress the normal gamma to alpha transformation. When, however, just sufficient of the alloying element is added to suppress entirely the A_3 change-point of iron, an austenitic or gamma alloy results, and it is well known that the austenitic state possesses certain definite properties. A relatively high maximum stress with a good elongation is a property common to all austenitic irons. It is reasonable to suppose that austenitic iron alloys, however produced, will give similar properties.

Reverting for a moment to the manganese-iron alloys and the nickel-iron alloys, the maximum stress value is attained at a certain critical composition, the value of which must in some way be connected with the temperature of the transformation, and it is suggested that the maximum value coincides with that composition at which the transformation from gamma to alpha is completed, but which, at the same time, owing to the lowered temperature of the transformation, brings about the maximum distortion in the system. This infers that a structure similar in arrangement to martensite accrues at this critical temperature, and shows the connection between atomic distortion—or to use another term—random distribution of the atoms and their tensile properties.

Viewed in this light, the so-called martensitic structure in alloy iron must be regarded as being composed of a body-centred configuration in the state of maximum distortion. Nickel in this respect is the most useful of all alloying elements, because it lowers the gamma-alpha transformation without entering into combination with the carbon. Incidentally, it may be remarked that when the normal gamma to alpha transformation occurs at a temperature approximately below 150° C. water-quenching will not suppress the change, since the normal rate of cooling between 150° C. and 0° is almost the same in water which has been heated by the hot specimen as it is when cooling in air.

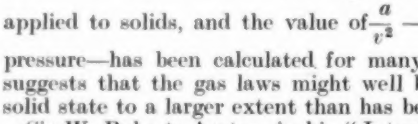
Thermodynamic and Alloy Systems.

From what has been said, it is evident that space-lattice determination of the elements is not alone sufficient as a means of investigating alloy systems, and other methods of attack must be brought to bear on the problems. For instance, there is the possibility that a distorted structure may be composed of a considerable amount of amorphous material, which is completely masked by the crystalline elements when examined by means of the X-ray.

An examination of the periodic table reveals the interesting fact that most of the elements in Groups 1 and 2 are insoluble in iron. Elements in Groups 4, 5, and 6 tend to retain the alpha or body-centred form, whilst elements in the 8th Group tend to retain the gamma or face-centred form. Generally speaking, elements of low atomic volumes retain the contracted or gamma state. There are, of course, certain exceptions to the general rule. It is interesting to note, however, that an element, when added to iron, functions in some relation to its place in the periodic system, which suggests that it is the properties of the atom, rather than the crystal, that must be looked to for the development of metallurgical theories.

There can be no doubt that a considered application of the laws of thermodynamics would assist in solving many problems at present unknown. For instance, it has been shown that the Van der Waal equation of state can be applied to solids, and the value of $\frac{a}{v^2}$ —*i.e.*, the intrinsic pressure—has been calculated for many elements. This suggests that the gas laws might well be applied to the solid state to a larger extent than has been in the past.

Sir W. Roberts-Austen, in his "Introduction to Metallurgy," instances the remarkable similarity between the P–V curve for a gas and the stress-strain curve of a steel showing a drop at the yield value. In the figure is shown the form of the P–V curve for carbon-dioxide gas, whilst alongisde this is plotted a typical stress-strain curve. It will be noticed that the P–V curve has been plotted in a direction reverse to what is usual. Considering for a moment the P–V curve, it will be seen that as the pressure is increased, at a certain P value the gas liquefies, giving rise to a horizontal branch in the curve, and finally, with further increment of pressure, a solid form. Viewing these changes in the reverse manner, starting with the solid, as the pressure is decreased the solid becomes converted first of all into a liquid and then into a gas.



Considering now the stress-strain curve; when a test-piece is pulled in tension the effect of a load is to decrease the internal pressure and increase the volume. The relation between pressure and volume is linear up to the elastic limit, and corresponds with the effect of decrease in pressure on solid carbon dioxide. A further increase in load, which again infers a decrease in internal pressure with respect to the metal, gives rise to the horizontal branch. This suggests that slip takes place due to the

formation of liquid along the slip planes, followed by an almost instantaneous solidification of the same. As the load is further increased, atomic distortion would take place in the mass as a whole, resulting in a random distribution of the atoms, giving a state equivalent to that of a gas.

This conception is of necessity largely hypothetical and imaginary, and is given with a view to suggesting a more detailed study of alloy systems from the standpoint of the gas laws.

Whether or not random distribution of solute atoms in an alloy system, as detected by X-ray examination, can be likened to the gaseous state, is perhaps not as yet proved. If it is the case, then the pressure factor, so largely ignored on account of its phase law considerations, may be found to play its part in our theoretical conceptions.

The Principle of Le Chatelier.

The principle of Le Chatelier may be stated as follows :—Every change in one of the factors of equilibrium produces a transformation in the system, tending to cause the factor in question to be changed in the opposite direction. In other words, an element which, when added to iron, brings about a contraction of the gamma lattice, will tend to cause its retention, whilst, on the other hand, an element which tends to bring about expansion of the gamma lattice will tend to raise the temperature of gamma/alpha transformation. Similarly, an element tending to cause an expansion of the alpha lattice will bring about its stabilisation, and *vice versa* when contraction is effected, the alpha to gamma transformation will tend to be lowered. It would therefore seem possible to view the effects of different elements upon the transformations in iron from the standpoint of the volume changes produced. At the same time, the tendency of the added elements to produce either an expansion or contraction in either or both lattices must not be neglected. This may explain the irreversible changes which are obtained in the nickel-iron systems. In other words, the "volume effect" of the added element must be considered, and it may be found that an irreversible change is due directly to the amount of expansion or contraction produced in the different allotropic states.

A Combination of the Principle of Le Chatelier and the Gas Laws.

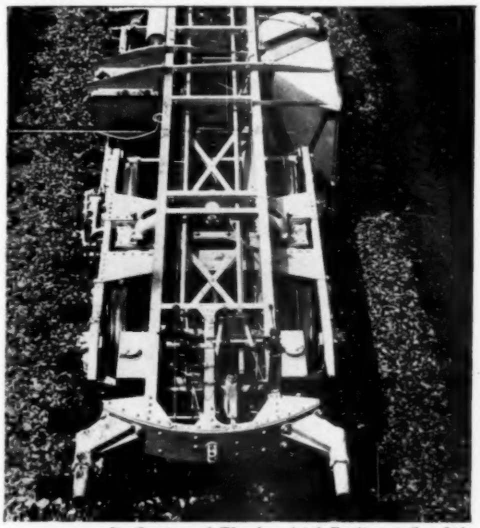
Having stated the possibilities of a part being played by the volume changes produced on alloying one metal with another, and having commented upon the possibility of applying the gas laws to metallic systems, it becomes conceivable that both phenomena may apply. The only way of applying the gas laws is to view the solute element as being in the form of a gas when X-ray analysis shows it to be in a state of random distribution. When in such a state the distribution of the solute element, and its resulting internal pressure, may be an effective medium in retarding or accelerating a change. Such a distribution infers that the solute elements are not part of the normal lattice configuration, but, taking up some position external to the lattice, may produce effects entirely different from what would be the case if they formed part of the stable structure.

Consideration of Thermal Changes in Alloy Steel.

In certain nickel-chromium and other alloy steels containing varying amounts of carbon, the effect of initial temperature is pronounced. For example, a steel containing approximately 3·5% of nickel, 1·5% of chromium, and 0·5% of carbon, will give rise to thermal changes, the temperature of which depends upon the temperature at which the steel has been heated prior to cooling. On cooling from just above the Ac change, a more or less normal transformation, occurring at 600° C., is found. On cooling from a higher temperature, the transformation is split into two, part of it now taking place at about 400° C., whilst if the temperature prior to cooling is raised above a certain minimum value, a single change at 400° C. is the only one recorded. If the carbon content is more than 0·75%, a further transformation occurring at 150° C. may be produced according to the initial temperature. Briefly, in a hypo-eutectoid steel, two changes, occurring either together or separately, are usual, whilst in a hyper-eutectoid three transformation are possible. The writer has given different explanations for this phenomenon in the past, but it cannot be said that a conclusive reason has as yet been derived, and one begins to wonder whether the distribution of the carbon, which alone may possibly be the cause of these variable transformations, should not receive greater consideration. Can it be that at the higher temperatures the carbon is distributed in such a way that the pressure effect may be looked upon as being the cause of these variations? Even more peculiar results are obtainable in certain chromium-carbon steels, where, notwithstanding the fact that the normal Ac_1 and Ar_1 change occurs at a temperature higher than in a corresponding plain carbon steel, cooling from a high temperature brings about a marked lowering of the transformation. It is unfortunate that so little information exists with respect to the thermal changes of co-ordinated series of alloy steels. Naturally, the determinations necessary for a quarternary system are almost too great to be undertaken by one worker alone, and the only means of arriving at a satisfactory solution of the problem of initial temperature in relation to its effect upon the critical transformation would seem to be co-ordinated research undertaken by different research institutions on one particular system.

Microstructure in Relation to Mechanical Tests.

An examination of microstructures, particularly of alloy steels, reveals one important fact—namely, that in the oil-hardened and tempered state it may be stated definitely that the finer the degree of distribution of the carbide particles, the higher will be the maximum stress of the steel. This in itself indicates that a random and—one might almost say—unstable dispersion of the constituents gives greater strength. The very fact that a martensitic structure which gives the highest tonnage is coincident with a low temperature change, at which the viscosity of the steel is too great to allow of a truly definite crystalline arrangement, in itself indicates that this is correct.



By Courtesy of The Associated Equipment Co., Ltd.

Part of chassis for a streamline rail-car supplied to G.W.R. by the Associated Equipment Co., Ltd. Nickel alloy steels and light aluminium alloys are used for several components of the engines and transmission.

In developing an alloy steel with a view to putting on the market a material which will give a high maximum stress consistent with good ductility in the tempered state, this feature should be borne in mind, and the alloy which will be found to give this property will be one which will change to martensite on oil-quenching, and only revert to the sorbitic state with difficulty.

It might be thought that a steel quenched so as to give

austenite, which on tempering will break down into martensite, might represent the ideal. Such, however, is not the case, for the temperature necessary to cause the breaking down of austenite will tend to cause a certain amount of tempering of any existing martensite. It is true that on tempering an austenitic steel martensite does not actually form until the steel has been cooled, the formation of martensite usually occurring at about 150° C., but for some obscure reason martensite thus formed does not seem to possess the high tensile properties found with martensite formed directly on quenching. This may be due, of course, to the incomplete transformation of all the austenite by a single tempering.

The Effect of Molybdenum on Alloy Steels.

Molybdenum is now added to many nickel-chromium steels with a view to giving increased strength without any marked reduction in ductility. With the usual molybdenum content of about 0·3%, it is usual to find a critical change in the neighbourhood of 400° C. Here again another problem confronts us. Molybdenum in itself raises the Ar_3 change in pure iron, and yet in the presence of carbon a marked lowering of the Ar_1 change is brought about. This peculiarity must be in some way due to carbide formation. It is not yet known whether special carbides exist as such at high temperatures in a solid steel, but in view of the marked segregation of molybdenum along with carbon in an ingot containing this element, considerable support is given to the view that molybdenum carbide exists as such at all temperatures in the steel. The small amount of molybdenum necessary to bring about this low temperature change indicates that the effect of molybdenum is almost phenomenal, and leads one to believe that the carbide which is formed has the power of remaining in the state of a high degree of dispersion at all temperatures, and which in some way or another makes it effective in bringing about a marked lowering of the transformation point. The insolubility of molybdenum carbide in the alpha state cannot be denied, as it is invariably found that very little segregation of the carbide particles occur, even after long time tempering of the molybdenum steel. Exactly what is the particular part played by molybdenum is a problem worthy of attack, and this instance is cited to show the paucity of our knowledge of many metallurgical problems.

Impact Brittleness.

Impact brittleness, or as it is sometimes termed, "temper brittleness," occurs in many alloy steels when these are allowed to cool slowly after tempering. It has been shown that both phosphorus and manganese may give rise to temper brittleness. At the same time, if the carbon content of the steel is sufficiently low, manganese brings about an increase in the izod value, rather than a decrease. For instance, a steel containing 1·5% of manganese and less than 0·1% of carbon on oil-hardening and tempering gives an impact value of 100 ft.-lb.

It has been suggested by the writer and others that this brittleness is due to a thin film of carbide being deposited around the grain boundaries during the time occupied in cooling from the tempering temperature to that of the atmosphere. It would seem that the addition of molybdenum gives rise to the formation of a carbide which behaves differently from all others. It is possible that this carbide has a negligible solubility in alpha iron, and thus the tendency of this carbide to segregate at the grain boundaries is completely absent.

Wire-drawing and Cold-working Operations.

If a rod of pure iron, free from carbon, is drawn into wire, a gradual increase occurs in the hardness, which reaches a maximum value about double that of the original when the percentage reduction has exceeded a certain value. If a carbon steel containing between 0·6 and 0·7% of carbon is likewise drawn, very little variation in hardness takes place until after a reduction of 50%, when the hardness begins to increase with further reduction. It will be noted that the two materials behave differently, no great increase in hardness occurring in the carbon steel until the cross-sectional area has been reduced to an appreciable extent. Moreover, the carbon steel wire in its finished state will give a maximum stress of over 100 tons per sq. in.

The explanation usually given for the increase in strength brought about by cold-drawing is simply one based on an increment in hardness produced by cold work.

Assuming the carbon steel, prior to drawing, to be in the sorbitic state, let us for a moment imagine that these fine particles of carbide are replaced by an inactive material, and ask ourselves the question—if this were the case, would any large increase in tensile strength result? It is extremely doubtful, and one is forced to believe that the carbide particles in some way play a part in the phenomenon.

When a wire is passed through a die it suffers considerable contraction at the point of maximum reduction, and at the same time heat is generated. According to the principle of Le Chatelier, the conditions at that point of the die which produce the contraction will induce all those conditions necessary for the formation of more contracted phase—*i.e.*, the gamma state. Can it then be that gamma iron is partially formed during the passes through the die, perhaps along the slip planes, and that this, along with the heat generated, will bring about a partial solution of the carbide, which momentarily gives rise to an austenitic state where solution has occurred? On cooling again, these planes become martensitic, and are in themselves largely responsible for the great increase in tensile properties. This is another application of the principle of Le Chatelier, and is given to illustrate possible extensions of this law.

This contention is supported by the fact that a drastically cold-worked steel tempers at the same temperature as martensite. The fact that there is no marked increase in the electrical resistance after cold-drawing may be due to martensite existing only or chiefly along the planes of slip.

On the basis of this suggestion, it is reasonable to suppose that an alloy iron in which the transformation on heating occurs at a temperature considerably below the normal change-point for iron would harden more readily on drawing. That is to say, a lesser degree of reduction would be required to produce the same relative hardness as compared with an alloy in which the change-point occurred at a higher temperature.

It is, however, interesting to note that in all steels which show a well-defined Ac_1, this invariably occurs at a temperature in the neighbourhood of 710° C. Further, whatever depression may be produced in Ar_1, the Ac_1 change occurs approximately at the same temperature. This leads one to believe that at a temperature of 700° C. the carbide is brought into a condition in which it becomes more soluble in alpha iron, and that the Ac_1 change would synchronise with the Ac_3.

Heat-resisting Steels.

Steels placed on the market which possess heat-resisting properties are usually of a highly complex nature, and the causes underlying the properties of a high resistance to heat are by no means understood. A critical examination of the problem reveals certain indications of the particular properties desirable in the manufacture of heat-resisting materials. In the first place, the steel must contain an element which either will not oxidise readily or, if it does oxidise, will give rise to the formation of an oxide of such a nature that it will provide an impenetrable cover to protect the internal structure. By "impenetrable" is inferred one impervious to gases. Further, if possible, the steel should be one which undergoes no phase change at any temperature, as otherwise the contraction or expansion undergone when passing through these transformations would obviously crack the surface and allow

gases to penetrate. Thirdly, this oxide coating should, so far as possible, possess a coefficient of expansion similar to that of the underlying material. Fourthly, it might be an advantage to incorporate in this alloy material an element which will retard—even entirely prevent—grain growth. With respect to this last feature, it is found that elements which retard crystal growth are those which, not being homogeneously distributed, diffuse but slowly. Tungsten is known to be in a somewhat segregated state in an alloy steel, and to diffuse slowly at high temperatures. Provided diffusion of any element is taking place, grain growth does not seem to develop to the same extent, for as one would expect, the act of diffusion in itself will serve to break down the large grains or not allow them to form.

Materials which are required to resist special gases should be so composed as to contain an element which will combine with these particular gases to form a suitable covering layer. For example, if it is required to resist sulphurous gas, elements should be added which will form with the sulphur compounds impervious sulphide combinations which would serve as a protective layer.

Steels Resistant to Corrosion.

Generally speaking, rustless and non-corrodible steels contain a high percentage of chromium, which, it is thought, gives rise to an impervious coating of chromium oxide—resistant to the attack of certain chemicals, and thus provides the necessary corrosion-resistant medium. The addition of nickel, by serving to retain the steel in the austenitic condition, further adds to the corrosion-resistant properties.

A peculiar feature of theoretical interest, with respect to the steels of the 18/8 type, is that in spite of the fact that these steels contain more than sufficient chromium to retain iron in its alpha condition at all temperatures, the addition of 8% of nickel converts the alloy into the austenitic or the gamma state.

It will thus appear that in so far as space lattice configuration is concerned, the effect of the chromium is to concentrate the nickel. This is another instance which serves to illustrate the impossibility of discussing the effects of different elements on iron from the standpoint of their crystalline structure.

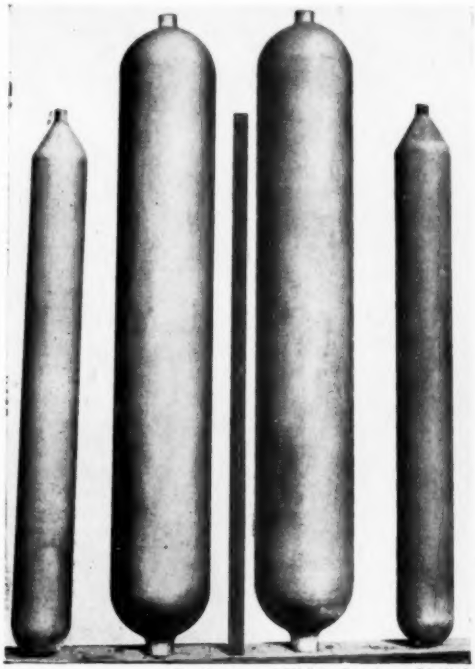
Most rustless steels contain a small percentage of carbon, which, under certain conditions of treatment, is precipitated around the grain boundaries, causing embrittlement of the structure as a whole. It would therefore seem desirable to make a rustless steel free—or almost free—from carbon, so that this phenomenon would then be impossible The writer, in collaboration with Mr. Chiang, has carried out some tests on a series of steels containing a maximum carbon content of 0·11%, with a chromium content of approximately 15%, and varying amounts of nickel. Tests on these steels were carried out by means of a Hounsfield tensometer machine, and after oil-quenching at 1,100° C. the results were as shown in table at foot of this page.

From these results it is evident that as the nickel content is increased, the maximum tensile strength is reached at a percentage of 7·5, with a corresponding reduction in the elongation. With 10% nickel, however, the elongation was almost phenomenal, and in the actual test carried out the bar stretched to the length of the machine without breaking or even necking. The particular steel was the only one which might be said to be completely austenitic under all conditions of treatment, and illustrates the effect produced by a low carbon content. Further, long-time tempering at 650° C., whereas it lowered the maximum stress of steels containing from 0·0 to 7·5% of nickel, had little or no effect on the 15/10 composition.

Conclusions.

It is evident from what has been said that the science of metallurgy is in a somewhat chaotic state in so far as alloy steels are concerned. Industrial alloys, containing as many as seven elements, are on the market and used daily, but it is difficult—if not impossible—to describe the functions of each of these elements when alloyed in such a complex manner. It has already been suggested that co-operative research carried out by the various research institutions is almost essential if progress is to be developed on correct and productive lines.

Whereas an element may behave in a certain manner in a binary alloy, the addition of a further element or elements may completely change its mode of action, and it is only when the behaviour of the separate elements can be related to definite physical properties that the true benefits of metallurgical science will be realised.



By Courtesy of Vickers-Armstrong Limited.

Group of four high-pressure cylinders in Vibrac nickel chromium molybdenum steel, used in connection with the propulsion of motor vehicles by compressed gas. The two largest cylinders are for use at the compressor station, whilst the two smaller are for containing the compressed gas on the vehicle.

Of the elements commonly used in alloy steels, nickel occupies perhaps the most interesting and prominent position. It is the only element which will bring about a marked lowering of the transformation points, and which at the same time enters into no combination with carbon. For this reason, alloys free from carbon will, one might imagine, be dependent entirely upon nickel as a strengthening medium. There are, therefore, vast fields of research awaiting those who have the means of investigating in an exhaustive manner ternary alloys containing varying amounts of nickel as the third element, carbonless alloys naturally being inferred, whilst an investigation of the more complex systems would follow.

In view of the fact that the lowering of the transformation point by nickel appears to bear a more or less linear relation to the amount added, it would seem wise to vary the nickel content within fine limits, as from what has been said, there appears to be a critical position of the transformation point in every steel, which gives rise to the best tensile properties. No satisfactory explanation has yet been given for the

HEAT TREATMENT : O.Q. 1,100° C.

Steel.	Cr. %	Ni. %	Y.P.	M.S.	E. %	R.A. %	Break Stress.	Remarks.
A53	14·5	nil	41	52	22	38	46	Good curve.
54	15·0	2·4	50?	60·5	20	60	43	Bad curve.
55	14·5	4·9	61?	74·5	20	55	47	Curve shows a peak.
58	14·5	7·4	45?	82	10	18	82	Curve of non-ductile material.
59	14·[illegible]	9·86	10	about 50 tons	unbroken at 75*	—	—	Unbroken.

* This test piece was stretched to the limit of the machine as then constructed, at 75% reduction was unbroken and showed no signs of necking.

irreversible transformation common to all nickel-irons and nickel steels, and it is interesting to bear in mind that in so far as is known, whatever the transformation on cooling may be, in a nickel steel containing carbon the Ac_1 point occurs either at 700° C. or above.

It would be extremely valuable to derive an alloy steel with a low transformation point on heating. If such a discovery was made, it might be found that this alloy would harden very rapidly when drawn through a die.

In spite of the large number of alloys on the market, and the fact that the engineer has no difficulty in selecting a composition suited to his particular requirements, there still remains a vast amount of work to be done with a view to creating something even better. Most of these revolutionary compositions are due rather to methods of "hit and miss," and the object of the scientific metallurgist should be to substitute for this unsatisfactory method one, more certain and scientific, capable of producing the required article rapidly and in a more satisfactory manner

There is little doubt that industry would be well advised to become more enthusiastic over scientific investigations, for provided such were carried out not only on scientific lines, but with a view to supplying industry with fresh materials for their markets, all round benefits would accrue.

[We are indebted to the Mond Nickel Co., Ltd., for permission to publish this the third article of a series dealing with alloy steels. It is shortly to be published by the Bureau of Information on Nickel, Thames House, Millbank, London, S.W. 1.—Editor.]

Service Characteristics of the Light Metals and their Alloys.

This report was prepared to present in convenient, concise form essential technical data and information for aluminium, magnesium, and their more important alloys. It is arranged in four parts: metallurgical characteristics, industrial requirements, surface protection, and tabular data. Under the first-named part there is discussion of chemical composition, heat-treatments, welding, etc. The section on industrial requirements evaluates the usefulness of light alloys in certain fields, including aircraft, automotive, general structural and architectural work, railway equipment, and household appliances.

While for most applications no surface protection is used, there are considerable fields of application when this is desirable. The discussion in the report covers painting anodising, or the artificial production of an oxide coating, and electro-plating. The latter two items apply specifically to aluminium. The section on tabular data includes sixteen extensive tables, covering trade designations, nominal compositions, physical constants, typical mechanical properties, and foundry characteristics of casting alloys. A bibliography completes the report.

Copies, in heavy paper cover, can be obtained from A.S.T.M. Headquarters, 260, S. Broad Street, Philadelphia, at 50 cents per copy. On orders for ten or more copies, special prices are quoted.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

Nov. 30.—Thomas Lowe Gray Lecture: "A Survey of Ships and Engines," by Loughman St. L. Pendred, C.B.E

Dec. 14.—"A General Comparison of Gas and Electricity for Heat Production," by A. H. Barker, M.A., B.Sc. M.I.Mech.E.

Royal Aeronautical Society.

Nov. 22.—"Air Turbulence Near the Ground," by Prof. Dr. Wilhelm Schmidt.

Nov. 29.—"Engine Research," by Captain A. G. Forsyth.

Dec. 6.—"Flaps and Other Devices as Aids to Landing," by R. P. Alston.

Dec. 16.—"Recent Research in Metallurgy," by Dr. W. H. Hatfield, A.F.R.Ae.S.

INSTITUTE OF METALS.

Birmingham Section.

Nov. 20.—"Fatigue in Metals," by H. J. Gough, M.B.E., D.Sc., Ph.D., F.R.S.

Nov. 29.—"Directionality in Some Annealed Non-ferrous Alloys," by R. G. Johnston.

Dec. 18.—"Interpretation of the Equilibrium Diagram," by N. P. Allen, D.Sc., M.Met.

London Section.

Dec. 5.—"Manganese Bronze," by Wesley Lambert, C.B.E. (Joint Meeting with Institute of British Foundrymen.)

North East Coast Section.

Dec. 15.—"Problems in Non-ferrous Foundry Practice," by F. W. Rowe, B.Sc. (Joint Meeting with Newcastle Branch, Institute of British Foundrymen.)

Scottish Section.

Dec. 10.—"Improvements in Surface Condenser Tubes," by A. Spittle.

Sheffield Section.

Dec. 14.—"Rhodium Plating and Its Applications," by A. W. Scott.

Swansea Section.

Dec. 11.—"Refractory Materials of South Wales," by Prof. W. R. D. Jones, D.Sc.

INSTITUTE OF BRITISH FOUNDRYMEN.

Birmingham Branch.

Dec. 12.—"Cupola Practice with a View to Closer Carbon Control," by W. H. Bamford.

East Midlands Branch.

Nov. 23-24.—Joint Conference with London Branch (in London): (1) Visit to Works of the Ford Motor Co., Ltd. (2) Informal Dinner. (3) "Some Experiences in the Manufacture of High Grade and Alloy Castings," by P. A. Russell, B.Sc. (4) "Enamelling of Cast Iron," by B. B. Kent.

Dec. 8.—"Suggested Method of Establishing Melting Costs in a Grey Iron Foundry," by C. W. Bigg (at Loughborough).

Lancashire Branch.

Dec. 1.—"Foundry Costing," by J. Roxburgh.

Burnley Section.

Dec. 11.—"Points for Practical Foundrymen—Contraction Shrinkage, Chill and Camber," by A. Jackson.

Preston Section.

Dec. 5.—"Foundry Troubles," by C. C. Hodgson.

London Branch.

Nov. 23-24.—Joint Conference with East Midlands Branch.

Dec. 5.—"Manganese Bronze," by Wesley Lambert, C.B.E. (Joint Meeting with Institute of Metals).

Middlesborough Branch.

Dec. 14.—Report of Sub-Committee on Cast-Iron of the Technical Committee, by W. West.

Newcastle-on-Tyne Branch.

Nov. 24.—Lecture by H. J. Young.

Dec. 15.—"Problems in Non-Ferrous Foundry Practice," by F. W. Rowe, B.Sc. (Joint Meeting with Institute of Metals.)

Scottish Branch.

Nov. 30.—"Recent Developments in Silicate Enamels, and the Study of Their Industrial Uses," by E. E. Geisinger, B.Sc.

Dec. 8.—"The Work of the Technical Committee," by J. W. Donaldson, D.Sc., F.I.C.

Falkirk Section.

Dec. 15.—"The Patternshop—A Necessary Evil," by J. Nicholson.

Sheffield Branch.

Dec. 21.—"Further Notes on Defects in Steel Castings," by C. H. Kain.

Wales and Monmouth Branch.

Dec. 8.—Report of Sub-Committee on Cast Iron of the Technical Committee, by B. Bird (at Cardiff).

West Riding of Yorkshire Branch.

Dec. 8.—"High Duty Cast Irons in the Foundry," by G. Hall.

MANCHESTER METALLURGICAL SOCIETY

Nov. 21.—"Electric Furnaces," by A. Glynne Lobley, M.Sc.

Dec. 5.—"Steel Making Alloys," by W. F. Rowden.

Institute of Marine Engineers.

Nov. 29.—"The Work of the William Froude Experimental Tank," by J. L. Kent.

BIRMINGHAM METALLURGICAL SOCIETY.

Nov. 27.—"Austenite Cast Iron," by E. Morgan, B.Sc.

Dec. 4.—"Modern Sand Practice in a Specialised Foundry," by J. A. Nottage.

"Extraction of the Rarer Steel Alloying Elements," by R. G. Harper.

METALLURGIA

THE BRITISH JOURNAL OF METALS.

MACHINE TOOLS.

Developed on co-operative lines, immense progress has been made in the design and construction of British products.

THOSE who wish to obtain evidence of increasing optimism in the engineering industries, should visit the Machine Tools Exhibition now being held at Olympia. The machines displayed cover a very wide range, and it is significant that heavy and expensive machines form a considerable proportion of the exhibits. Practically all responsible British machine tool manufacturers are represented, while many representative German, American and Swiss machines assist in making the Exhibition international in character. It is generally considered that a reasonable time must elapse before machine tool developments are sufficiently widespread to warrant the high costs involved by such an exhibition, and manufacturers decided on an interval of four years, but in 1932, when an Exhibition was due under this arrangement, they wisely decided to postpone it in view of the industrial depression. The holding of this, the fifth Exhibition, is therefore an encouraging sign, indicating that, though we may not be experiencing an industrial revival, conditions are decidedly better, even so the machine tool manufacturers are to be congratulated on their enterprise and on the excellent Show they have presented.

As was expected, great changes in design have been effected since the last exhibition of the kind. At that time, new cutting materials were being developed and applied, which have had a revolutionary affect upon the machine tool industry. These developments facilitated machinery operations by means of increased cutting speeds and heavier feeds, which have assisted in meeting the demand for cheaper products, but the value of these developments has only been appreciated gradually, repeated failures with machine tools then in use, showing that special designs were necessary to obtain the amount of work from the new cutting materials, which has since been shown to be possible. The development of the hard cintered materials and their successful application for cutting purposes, influenced further progress in the manufacture of high speed steels, and the tendency towards finer permissible limits and improved finish has led to the development of diamond pointed tools, capable of cutting at very high speeds, while grinding, lapping and honing are being used to an increasing extent.

These developments have caused considerable investigatory and experimental work, in order that machines could be designed to meet the conditions each type of cutting or finishing tool required, particularly those which enabled higher cutting speeds and heavier feeds to be used. It was soon recognised, in such cases, that the rigidity of a machine was an essential requirement, and to resist the high stresses encountered, careful consideration had to be given to the grade and quality of materials forming parts, in order to exclude vibration in service ; various parts were subjected to excessive abrasion, and when made of ordinary materials their useful life was short. In order to supply the demands of the engineer, the machine tool designer found it advisable to take advantage of the developments in other branches of industry, and as far as the materials of machine tool construction are concerned, the metallurgist has contributed in no small degree. Not only has he supplied materials which have helped the tremendous strides in performance of machine tools, but he has developed heat-treatment which enhances the properties of the materials used.

The modern tendency in machine tool construction is to employ low alloy steels for parts requiring high strength coupled with high fatigue resistance. Even the cast iron, which invariably comprises the major part of the structure is frequently an alloy cast iron, the composition being designed to provide a strong iron, the casting from which is regular in structure and machines well. The general type of alloy steel used is not new. Some of the more familiar steels of this type have been known for many years, but it is only during recent years that they have been employed to any appreciable extent in machine tool construction. Probably the first to be used were the low nickel steels, then other alloy steels were added, including medium manganese steels, nickel-chromium steels, nickel-chromium-molydenum steels, the selection frequently being governed by cost providing the properties obtained are superior to the carbon steel of similar carbon content.

The application of alloying elements is not confined to steels employed ; in some instances it has been found that certain parts on machine tools wear very rapidly; particularly is this true of grinding machines. In such cases a material was necessary which would satisfactorily resist the combined abrasive action of the work and the grinding material, such, for instance, as centreless grinder supporting blades. After much investigation it was found that a nickel-chromium cast iron gave the best results, and blades have now been developed which effect considerable saving besides eliminating, in a large measure, the annoyance and delay of replacing worn supports.

Progress has not been confined to the application of metallurgical developments important as these undoubtedly are ; the machine tool designed has been quick to take advantage of the developments in electric driving and multi-speed motors, and reversing motors are being used to an increasing extent. Designers have certainly taken advantage of many improvements and developments that have contributed to the high quality of the modern machine tool, and they have done much to raise the standard of British machine tools to a level of efficiency comparable in every way with those made abroad.

There is another aspect of progress which is noticeable at Olympia, this is the degree of specialisation which has been developed. Manufacturers apparently recognise that a machine manufactured on general engineering lines can be manufactured in many other countries without greatly increased cost, but by manufacturing in Britain on a mass production basis, its manufacture in a country which has only a relatively small demand for it, could only be made in that country under the shelter of a very high protective duty or its equivalent.

It is worthy of note that machine manufacturers represented speak optimistically of the success of their venture ; practically all are more than satisfied with the inquiries and sales made, many in fact are so congested with orders that their works are not able to give delivery of machines for some months. We suggest that those who have not yet visited the Exhibition should make arrangements to see the enormous strides made in this important industry, before November 24, which is the closing date, if only to grasp the full significance of the co-operative spirit which is aiding the development of British machine tools.

NEW RAMPS CONSTRUCTED FOR DIRECT PLANE SERVICE.

DIRECT water transportation to the business section of New York City for both privately and commercially-owned planes is being provided by two floating seaplane ramps anchored in East River, one at the foot of Wall Street, the other at the foot of 31st Street. These ramps are of arc-welded construction, and were built from designs furnished by the United Dry Docks, Inc. and Edo Aircraft Corporation. The designs were requested by F. W. Zelzer, commissioner of aviation of the city of New York. The ramps were built by the department of docks at the Brooklyn Navy Yard.

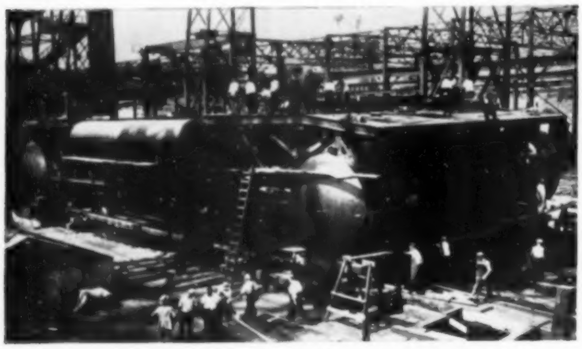


Fig. 1—Partially completed seaplane ramp, two of which will permit seaplanes to discharge passengers at the foot of Wall and 31st Streets on the East River.

The two ramps are 89 feet long by 56 feet wide, and weigh approximately 170 tons each. The structure of each ramp consists of two main steel buoyancy tanks which support five lanes of steel trusses covered with pine decking. Within the deck is a 45-ft. diameter power-driven turntable, the control mechanism of which is located in a small pit provided for the purpose.

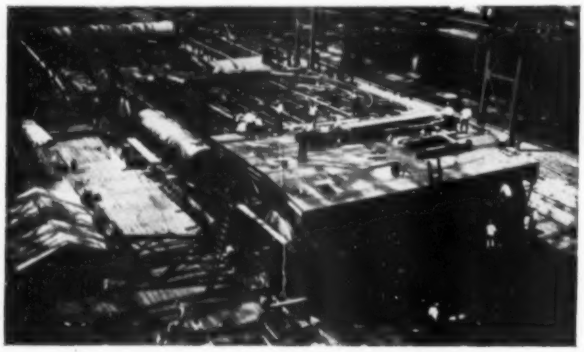


Fig. 2—View of one or two seaplane ramps, showing framework of 45 foot diameter turntable and partially completed pine decking.

The two buoyancy tanks are each 45 ft. long. The larger tank at the upper end of the ramp is 12 ft. in diameter; the smaller one at the lower end is 11 ft. in diameter. These tanks can be seen in Fig. 1. All the operating machinery is located in the larger tank. The smaller buoyancy tank is divided into four chambers or sections. The two end sections may be flooded or entirely emptied by means of two additiona, air chamber tanks, shown at the side of the ramps.

The 45-ft. turntable, which moves the planes from the low or submerged area to the upper dry section, is driven by a 10-h.p. hoisting engine. The circular channels under the framing of the turntable run over 100 rollers welded to the five sections of the circle of the top steel frame.

An air compressor driven by a 5-h.p. motor furnishes the air to the two tanks, 20 ft. long by 5 ft. in diameter, which serve both as air receivers and buoyancy tanks. These can be seen just beneath the circumference of the turntable in Fig. 2. Each ramp contains approximately 6,000 ft. of welding with a total of 7,000 lb. of welding electrode used in each. The welding was done by the J. K. Welding Company, using 12 welding machines and 14,000 lb. of electrode manufactured by The Lincoln Electric Company.

In operation, the seaplane lands on the submerged area of the turntable which is one-fourth under water. The ramp is then raised by pneumatic pressure from the two air chambers. This pressure is controlled automatically by mechanical control. The turntable is then revolved, carrying the plane to the dry upper area of the ramp.

Special Applications of Silumin*

For many years varnish manufacturers have been using with great success vessels made of pure aluminium with a flanged-on copper bottom, for boiling linseed oil. In some cases, however, pitting was found to occur on the inside wall of the vessels above the oil level. The cavities formed were always free from corrosion products, and of a round form, with sharp edges and a shell-like surface. Experiments carried out by Dr. G. Eckert showed that the pitting is caused by an undue overheating of the linseed oil. When in the experimental vessels made of pure aluminium, the oil was heated to 250 to 300° C. no pitting occurred, but this was the case when the oil was heated to 320 to 350° C. In practice pitting can, therefore, be avoided by accurate temperature control.

In further experiments the behaviour of several aluminium alloys when exposed to the action of boiling linseed oil was examined. Sheet samples of aluminium, Pantal, KS-Seewasser, BS-Seewasser, and silumin were riveted to the inside wall of an aluminium vessel in the zone where pitting generally occurred, and then linseed oil was heated in the vessel to 350° C. for six to seven hours. Of the alloys tested silumin was the only one which remained unattacked. This good behaviour of silumin was confirmed in further tests in which linseed oil was heated, up to 400° C. in vessels made of silumin sheet. In all cases the vessels stood the test.

Silumin proved also wholly resistant against the attack of boiling high-molecule fatty acids, boiling aniline, and boiling butyl alcohol by which substances aluminium is destroyed in a short time. By boiling carbolic acid silumin is attacked to a lesser degree than aluminium. A copper content of up to 5% does not affect the corrosion resistance of silumin. Further tests showed that all aluminium-silicon alloys with silicon contents of, at least, 3% behave like silumin.

Gas Firing Improves Die-casting Practice.

Production has been increased 15 to 18%, and fuel consumption reduced as a result of changing from oil to gas firing in a large die casting plant. The fuel now used is coke oven gas at 10 to 15 pounds pressure. It is the practice in this plant to permit metal in the pots to solidify at the end of the day's operation. Melting down is started at 2 o'clock in the morning with a gas pressure of 2½ to 3 pounds at the burner, and the metal gradually rises to a temperature of 1,250° Fahr., and is held at that point until the operators are ready to start.

Previously with oil it was the practice to have a more rapid melt-down for the reason that less fuel was consumed and heating the metal to higher than the required temperature was avoided. Included in the advantages of gas firing is the fact that the metal always is at the proper operating temperature when workmen arrive in the morning and no delay is encountered in getting into production. Since the change was made, life of the pots has averaged 16 weeks, compared with the old average of 11 weeks. Rejects due to casting at improper temperatures practically have been eliminated.

* Extract from "*Aluminium*," Sept. 1934.

The Treatment of Cast Iron with Sodium Carbonate

Some Features of Progress in its Technique and in the Design of Equipment for its Operation

By a Special Correspondent

THE use of sodium carbonate as a refining flux at various stages in ferrous metallurgy has been the subject of a considerable amount of research during the last four years, and in this country and elsewhere it has rapidly established itself as standard foundry practice. As a desulphurising and refining agent, this common industrial chemical now finds widespread application on an everyday commercial scale in foundries engaged in the production of high-grade iron castings in which soundness and machinability are of first importance. The process itself and its latest modifications have been described in detail from time to time in this journal,[1] and its general significance in cast-iron production needs no emphasis here. Granted the injurious nature of segregated sulphur in cast iron, it may suffice to mention the accumulation of this element resulting from the repeated melting of scrap in foundry mixtures in the cupola. A cheap and simple method of removing sulphur, such as is offered by the use of sodium carbonate, must result in considerable reduction in costs, since it permits of the safe use of scrap in reasonable quantities in the cupola process.

The increasing manufacture and use of items of foundry equipment specially designed to facilitate and speed up its operation is one of the surest indications of the rapid development of the sodium carbonate process. Particularly is this the case with forehearths and ladles, modifications of which have been referred to from time to time in the technical press.[2] It is the purpose of this article to describe these developments in greater detail.

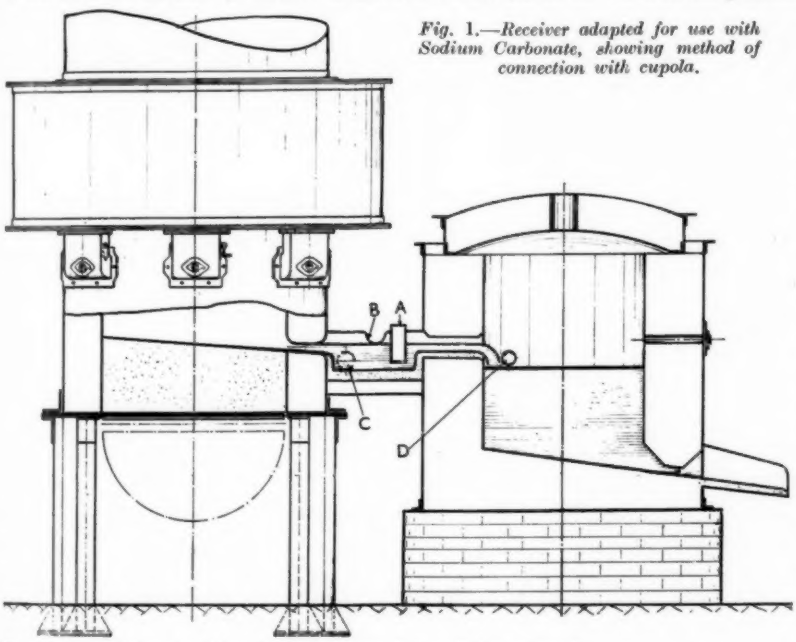


Fig. 1.—Receiver adapted for use with Sodium Carbonate, showing method of connection with cupola.

The Forehearth or Receiver.

The use of a forehearth or receiver in cupola melting processes is well-established practice, and its advantages are several. It results in efficient separation of slag and metal, at the same time ensuring that the iron does not remain for a long period in contact with the bed-coke of the cupola, with consequent absorption of carbon and sulphur.[3] Its purpose is, in general, to eliminate variations in the composition of the metal, and to enable a sufficient volume of metal to be collected which can all be tapped in one batch.

The advantages of such an arrangement where sodium carbonate treatment is concerned are obvious, since it allows the process to be conducted without any interruption of the pouring routine, sodium carbonate being added at intervals in proportion to the flow of metal. The older type of receiver, however, is not in general adapted for use with sodium carbonate, and modifications in design have accordingly been introduced which are dictated by two main requirements. The first of these is a receiver which is not worked under pressure, and which can therefore have a permanent opening in the top for the introduction of the sodium carbonate. In the older type, provision is usually made for their pre-heating to some extent by hot gases from the cupola, with the result that they have to be kept permanently sealed at the top, and worked at the pressure of the blast.

The second requirement is a means of preventing cupola slag from entering the receiver and coming into contact with the sodium carbonate slag. Cupola slag invariably contains silica, and its harmful action in the receiver or ladle is illustrated by the reaction:

$$Na_2S + SiO_2 + \frac{MnO}{FeO} \longrightarrow Na_2O.SiO_2 + \frac{MnS}{FeS}$$

—which is, in effect, a reversal of the main desulphurising reaction:

$$Na_2CO_3 + \frac{MnS}{FeS} \longrightarrow Na_2S + \frac{MnO}{FeO} + CO_2$$

A Specially Adapted Receiver.

A receiver designed to fulfill both these requirements (due to Messrs. Pneulec, Ltd., of Smethwick) is shown in section in Fig. 1, showing its design in relation to the cupola. The opening for the addition of sodium carbonate is shown at the top of the receiver, and since this arrangement does not admit of pre-heating by the cupola gases, a sufficient thickness of refractory lining is necessary in the receiver to act as an efficient insulator, and so to prevent undue cooling of the metal. Before starting to fill this receiver, it is usual to pre-heat it by means of an oil-fired burner.

The second requirement, that of efficient cupola slag separation, is satisfied by the ingenious design of the connecting launder between the cupola and the receiver. This launder takes the form of a shallow well, in which is inserted a syphon brick (A), which effectively prevents

1 METALLURGIA, March, 1934, p. 158.
2 *Foundry Trade Journal*, April 5, 1934, pp. 223–226.
3 Moldenke, "Principles of Iron Founding," pp. 416–417.

Fig. 2.—Showing receiver in working position, with details of syphon brick channel.

the passage of slag into the receiver. A constant level of molten metal is maintained in the launder well, and is free to pass under the brick, whilst any slag which collects on the cupola side of this brick is run off from the surface through a continuous slag spout (B). Before starting a day's run, the receiver tap-hole is plugged, and metal tapped from the cupola up to the level of the continuous slagging spout. After this the arrangement functions continuously. A tap-hole (C) is provided for the purpose of draining the syphon brick channel at the end of a " blow."

Operating Principles with Sodium Carbonate.

Enough metal to cover the taphole of the receiver is first tapped from the cupola, after which sodium carbonate is introduced through the top in amount sufficient to treat the full metal capacity of the receiver. This operation ensures that no carbonate is trapped in the receiver tap-hole, since this would be liable to escape with the metal when tapped. A slag-spout (D) is provided in the receiver, just below the level of the connecting launder, for the purpose of running off accumulated sodium carbonate slag.

The photograph (Fig. 2) shows a receiver of the type described, in its working position, and Fig. 3 shows the receiver being tapped. The open top for introducing carbonate, the connecting launder, with its syphon brick and slag spout, and the slag hole in the receiver for running off soda slag, are all clearly visible in the first photograph. The removable cover, provided for ease in " fettling," is also worth noting, but it may be remarked in this connection that " fettling " is in any case an easy matter when sodium carbonate is used, and is called for much less often. The soda slag has been found actually to keep the refractory lining of the receiver clean, its fluidity being such that it does not tend to accumulate on the walls, as would be the case with ordinary cupola slag. Nor need attack on the refractory lining be feared. Provided that the lining is made of a close-grained firebrick, preferably containing 35–40% of alumina, and with the joints in the brickwork kept as thin as possible, or alternatively a tamped lining is provided, it will be found that the reaction of the sodium carbonate with the refractory is practically confined to the surface, which becomes glazed over.

This method is also an economical one, so far at least as sodium carbonate is concerned. After the first addition of carbonate (which should be in the proportion of 1 lb. for each cwt. of metal which the receiver will hold when full) it is only necessary to make further sodium carbonate additions of $\frac{1}{4}$ lb. to $\frac{1}{2}$ lb. for every further cwt. of metal passing through—the reason being that a considerable amount of soda slag remains in the receiver, which it is only necessary to revivify at intervals.

Sodium Carbonate in the Ladle.

Treatment with sodium carbonate, at any rate in mass production foundries, can be best performed in a receiver, as this makes the refined metal available for distribution in the moulds without having to treat each ladle separately. In many foundries, however, it is not possible without major structural alterations to install a receiver, as the cupola may not be built sufficiently high above the ground level. In such cases, certain of the advantages of the receiver (in particular, the possibility of pouring absolutely clean metal) can be obtained by the use of ladles fitted with either " tea-pot " or " kettle " spouts acting on a syphon principle similar to that above described in connection with receivers and enabling metal to be drawn from the bottom. These new ladles may either have a partition fixed on the inside, perforated at the bottom with a hole of sufficient size for the required flow of metal, or else a hole is cut in the ladle wall near the bottom, and a teapot spout welded on to the outside of the ladle. The first-mentioned principle is adopted in the " Collin " patent kettle-spout ladle, shown in section and elevation in Fig. 4, and reproduced here through the courtesy of Messrs. John A. Smeeton, Ltd., London. Only clean metal will pass up the kettle spout, the inlet to which is seen near the bottom of the ladle, and which is formed by the perforated partition plate sliding into two small angle or channel irons rivetted or welded down the inside of the ladle body. This partition is extremely easy to replace, and simplifies the lining of the ladle generally. The ladle

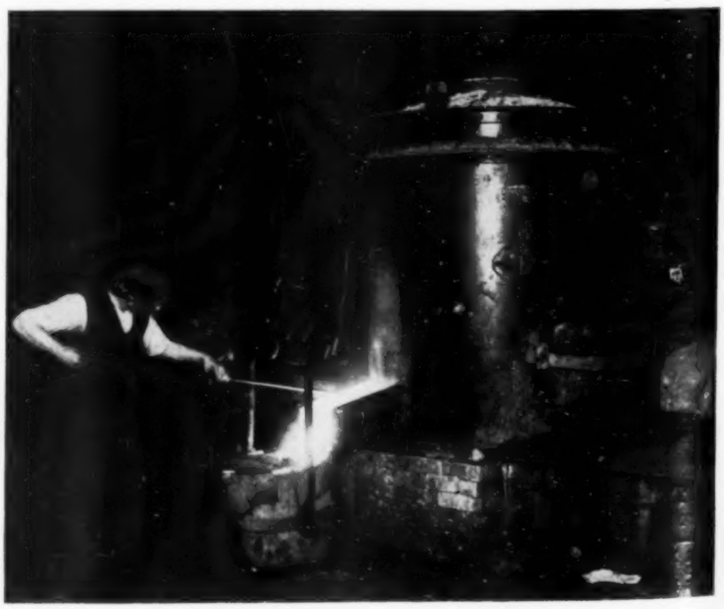


Fig. 3.—Showing receiver being tapped.

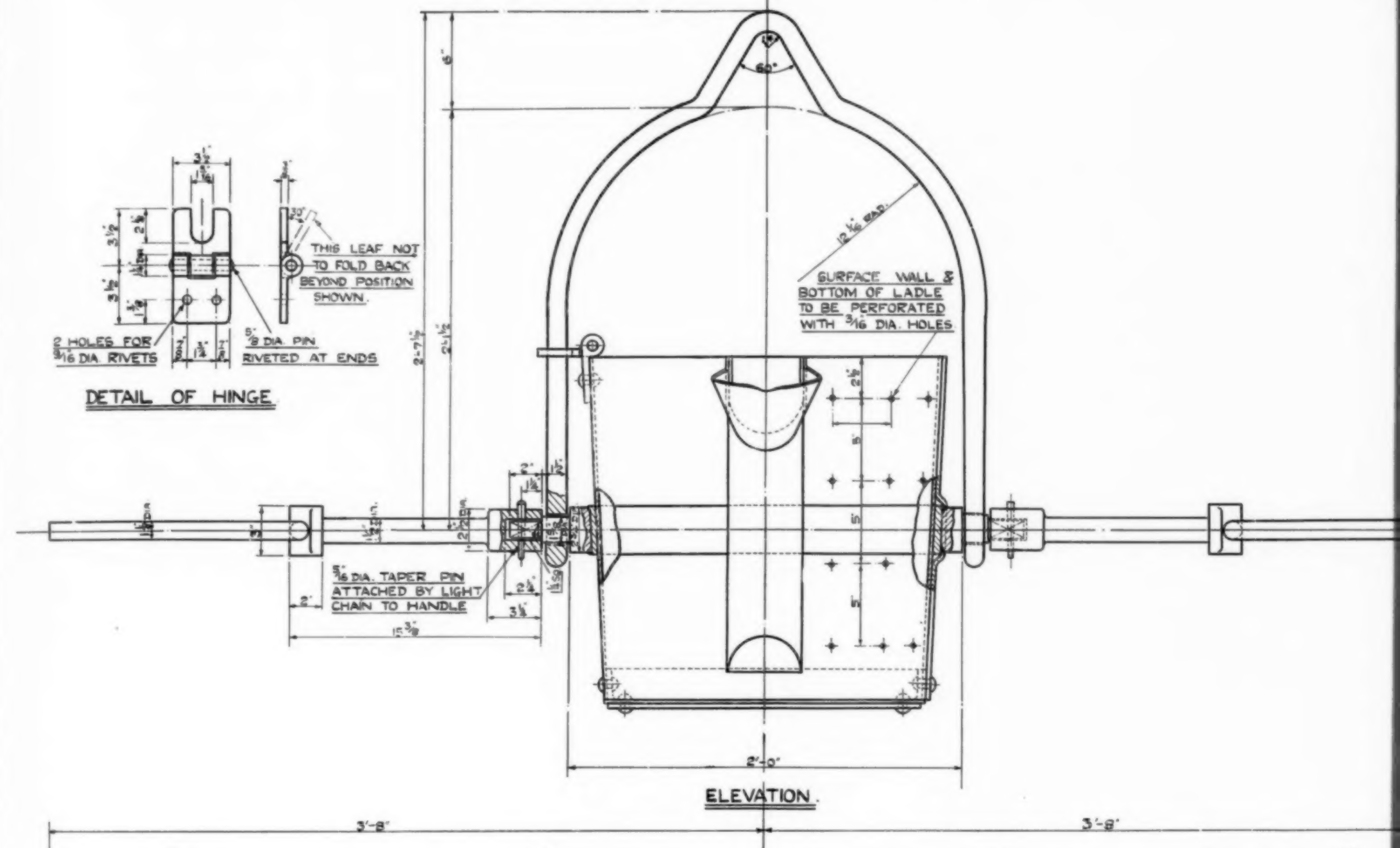
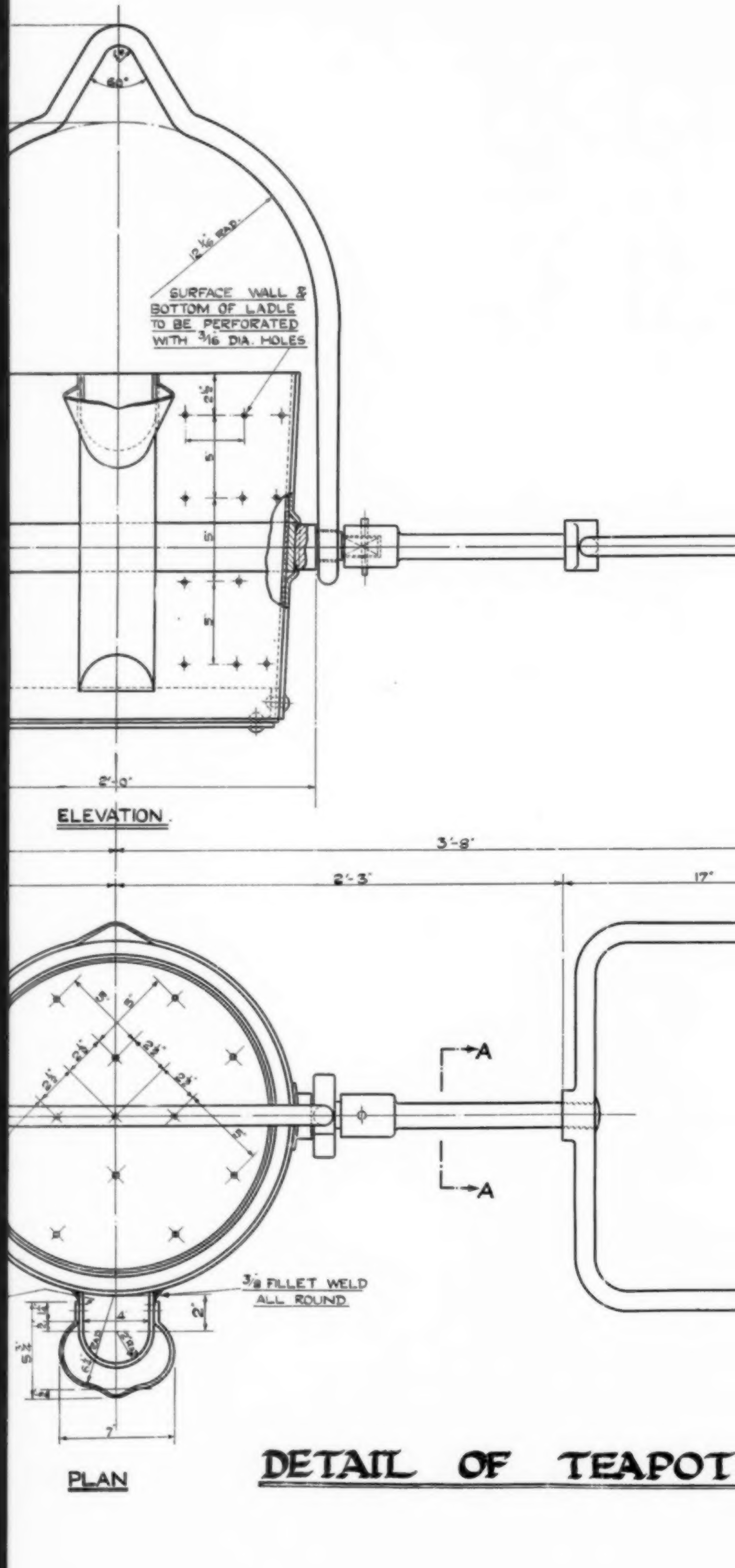
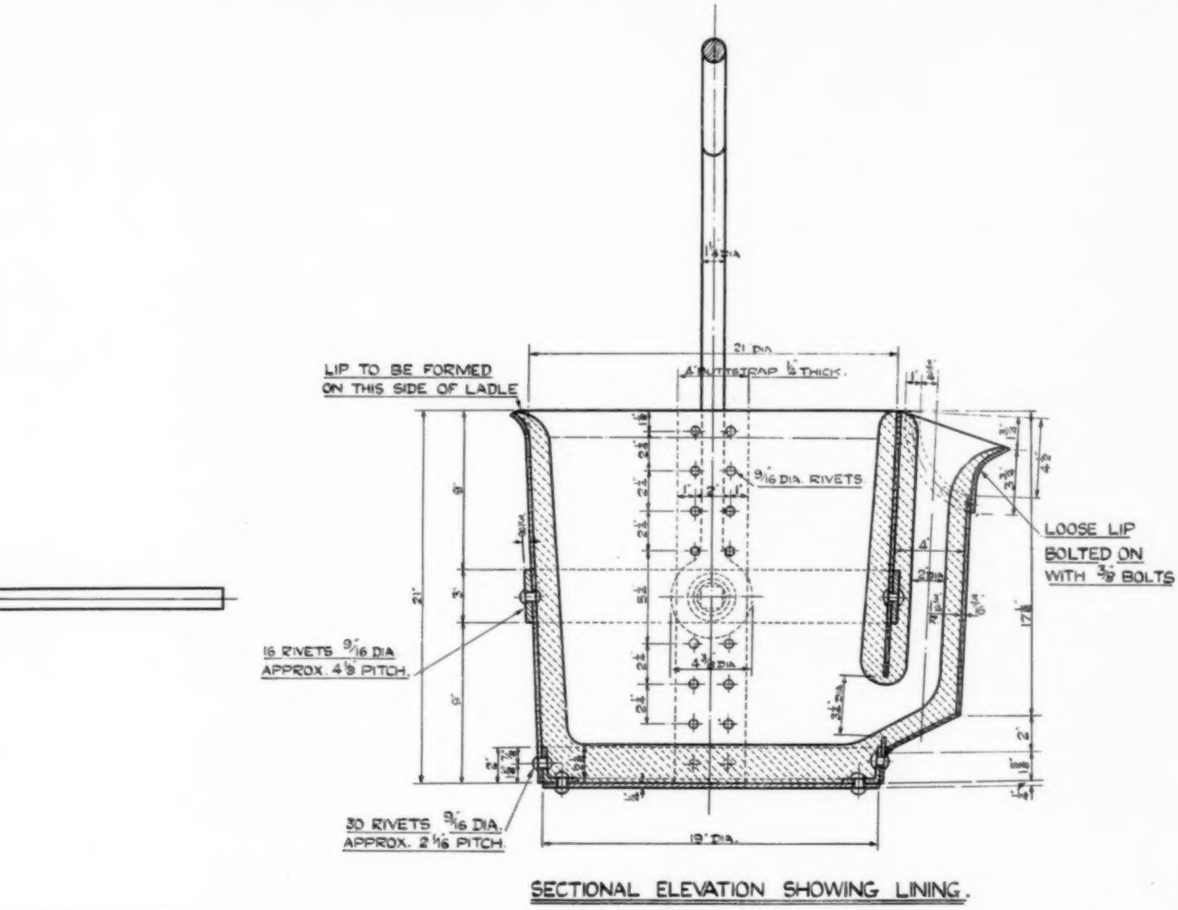


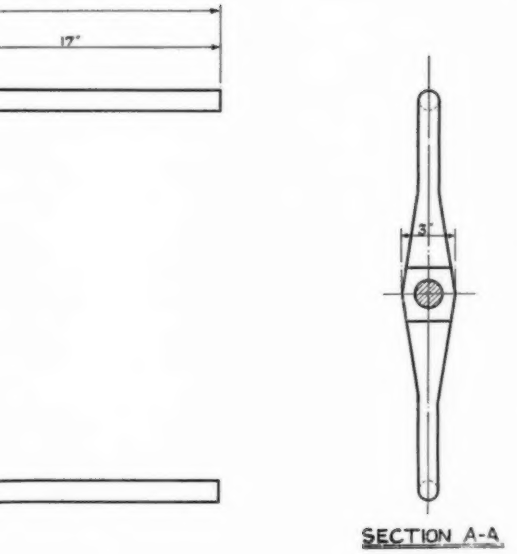
Fig. 5.

DETAIL OF TEAPOT



DETAIL OF TEAPOT





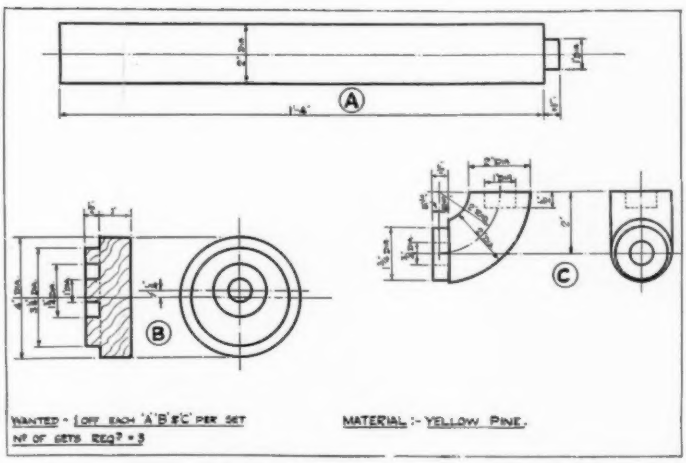


Fig. 6.—Detail of Spout Cores for 2" Bore Spout.

...POT LADLE.

illustrated weighs approximately 5 cwt., and has a holding capacity of 20 cwt. when lined.

The accompanying insert (Fig. 5) shows the construction and dimensions of a "teapot" spout ladle of approximately ½ ton capacity. The "Collin" type may have advantages in certain classes of work, particularly in the fact that a larger unrestricted stream of clean metal can be poured with a minimum chance of slag obstacles, and in the

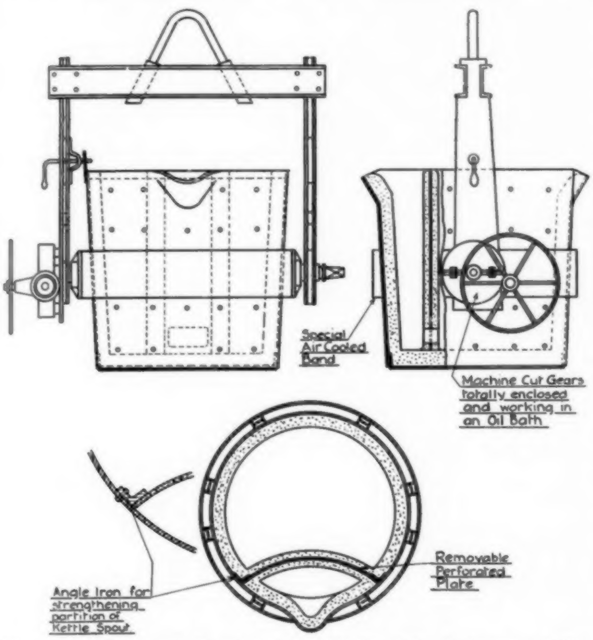


Fig. 4.—Sections and elevation giving details of the kettle-spout ladle.

ease in which the lining material can be applied by hand. This is done simply by lining the ladle body, leaving the angle irons uncovered, then daubing the plate on both sides with fireclay, and sliding into position. In the type with the external teapot spout, lining of this is carried out quite simply by ramming the refractory material round a pine-wood core, which is afterwards withdrawn. The diagram (Fig. 6) shows the detail of the latest design of template for this purpose, constructed in three separate parts, to facilitate its extraction.

Speeding up the Process.

When the sodium carbonate process is being used in the teapot ladle, the normal method of treating with a mixture containing approximately equal quantities of granular sodium carbonate and ground limestone is adopted. Sufficient metal to seal the bottom hole leading into the spout should first be tapped into the ladle, since obviously no soda slag should be permitted to get into the spout. The required amount of limestone and sodium carbonate is then added, and metal tapped on to it either all at once or in as many stages as the particular case demands. In cases where the maximum degree of desulphurisation is required, sodium carbonate can be used alone without any risk of the fluid soda slag running into the moulds; but it will usually be found advisable in such cases to add the ground limestone when the ladle is full, so as to facilitate the subsequent skimming or emptying of the slag from the ladle over the lip on the opposite side to the teapot spout.

It has been thought worth while to describe these advances in foundry equipment in some detail, since their adoption can hardly be said to have kept pace with that of the sodium carbonate process. The practice of continuous slagging at the cupola (which is practically universal on the Continent) certainly merits more attention by foundrymen in this country, and where sodium carbonate is used, whether in the cupola, receiver, or ladle, it is an essential for the maximum efficiency of the process. It might be noted that the cupola attachment to the receivers above-described in no way prevents the cupola being used in the ordinary way without a receiver if desired, for the making of common grade castings. Although the arrangement is not usual, the cupolas can be fitted with an ordinary tapping spout.

It is certainly remarkable that, with the growth of the sodium carbonate process in this country, foundrymen in general should not have been quick to realise the advantages of bottom-pouring in connection with it, and that ladles of the teapot or kettle-spout types are not more widely used. The speeding-up of the whole refining process which results from their use should be evident from the fact that there is no need to interrupt the tapping process while the flux is being added, and that it is not essential to deslag the ladle before pouring—although this may be done for the sake of convenience, if desired. The device may be regarded, in fact, as a mobile form of receiver. When such ladles are used in the modified technique, using ground limestone mixed with the sodium carbonate, no time is lost in waiting for the slag to rise to the surface—an advantage which makers of small and intricate high-grade castings should be quick to recognise.

The Blast Furnace.

Prof. C. O. Bannister, in his address as Chairman of the Liverpool Section of the Society of Chemical Industry, at the Section's first meeting in the 1934–35 session on October 26, made some interesting observations on the blast furnace and its use as a chemical plant. He pointed out that for every ton of iron produced, some 5½ tons of combustible gas left the furnace. The world's production of iron in 1929 was 97,000,000 tons, which involved the production of an enormous quantity of combustible gas.

From Scottish districts, using splint coal as fuel instead of coke, considerable amounts of tar and ammonia were formerly recovered, but coal-fired furnaces were rapidly becoming mere memories of the past. He described the recent Russian experiments on the use of a mixture of oxygen-enriched air and steam as a blast for the production of a waste gas which, by subsequent conversion of the carbon monoxide, yielded a gas containing suitable proportions of nitrogen and hydrogen for the manufacture of synthetic ammonia.

Prof. Bannister also described the recovery of potash from blast-furnace gases under special circumstances, and the removal and recovery of zinc from certain blast-furnace charges. Lastly, he dealt with the use of blast furnaces for the production of phosphorous and phosphoric acid by direct reduction and fluxing of mineral phosphates and silica, the phosphorous being volatilised and recovered.

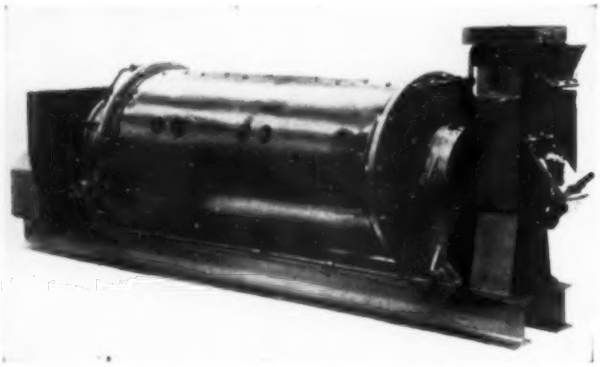
Speed Planes and Materials.

The design and manufacture of the three D.H. "Comets" by The de Havilland Aircraft Co., Ltd., in the short time at their disposal was an achievement of considerable merit. It is worthy of note, however, that the high-grade materials upon which the successful flight of these machines depended were available. In this connection a notable feature is the fact that the power developed by the engines was transmitted by drop-forged crankshafts manufactured by English Steel Corporation, Ltd. The alloy steels and drop-forged crankshafts of this company have played an important part in all record flights made in British machines, and it is noteworthy that practically all the British aircraft which took part in the England-Australia air race (10 out of 14) relied upon drop-forged crankshafts, manufactured at Vickers' Works, and 12 out of 14 used alloy steels made by English Steel Corporation, Ltd. It is doubtful whether a more severe test of the design and materials used in construction could be arranged than in this race, and it must be very gratifying to those responsible for much of the investigatory work leading to the development of materials that they have withstood the severe stresses encountered in the race so satisfactorily.

PULVERISED FUEL FIRING.

For the general operation of furnace settings with pulverised fuel great interest attaches to the latest designs of the "Kennedy" tube mill. Although opinions differ on the subject, the unit system is now generally regarded to possess a number of advantages, both for steam boilers and metallurgical settings of all kinds, in comparison with the bin and feeder system, such as simplicity, convenience, small floor-space, and low maintenance costs. One of the main requirements also of economical, reliable, and efficient pulverising is slow speed.

Manufactured by the Sheepbridge Coal and Iron Company, Ltd., the "Kennedy" mill is a short, horizontal, air-swept tube mill, with forged-steel balls, running under the slow-speed conditions of 17½ to 50 revs. per min., according to the size, without noise or the emission of smoke and dust.



An air-swept tube pulverising mill.

This mill reduces bituminous coal direct, in one operation, to a degree of fineness equivalent to 85 to 95% through a 200-mesh screen, and 60 to 75% through a 300-mesh screen, while the total maintenance costs do not exceed about 1½d. per ton of bituminous coal. Also coal up to 15% moisture can be pulverised without pre-drying, as well as other solid fuels, such as anthracite, coke, coke breeze, petroleum coke, and tar residues.

It is hardly necessary to emphasise that such fine pulverising is of the utmost importance for rapid and efficient combustion, and the results are much superior to the ordinary figures of 90% through a 100-mesh screen, and 70 to 80% through a 200-mesh. Coal also can be taken direct when in pieces not over about ¾-in. size being supplied continuously from the hopper of the mill by a special design of motor-driven disc feeder. The air current passing through the mill to the burners, giving automatic grading of the coal particles by gravity flotation, is provided by a variable speed self-contained fan, while no screens of any kind are used, and no magnetic separators. These are not necessary, since tramp iron or similar hard material merely helps the grinding. Almost the only wear and tear is on the steel balls, and mills of this type have pulverised up to 20,000 tons of coal without any renewals except the balls. Noise and dust are eliminated by the simple principle of preventing them from escaping.

With regard to the mill drive, various methods are supplied, according to the conditions, including for example direct gear drive from an electric motor with a double helical pinion on the motor shaft engaging with a large gear-wheel on the mill cylinder at the opposite end to the coal feed. Notable also for still more silent running is a worm gear drive operating in a closed oilbath, with the worm on the motor-shaft engaging with a worm wheel on the hollow trunnion of the mill. Included is forced lubrication for the main bearings with continuous circuit of the oil to and from a reservoir through a cooling coil.

New Specifications Approved.

On the recommendation of its Committee A-1 on Steel, the American Society for Testing Materials has accepted for publication as tentative two specifications covering (*a*) alloy-steel castings for valves, flanges and fittings, and (*b*) seamless alloy-steel pipe, the materials being for service at temperatures from 750° to 1,100° F. There have been urgent demands from industry for these specifications. The specifications for alloy-steel castings include eight classes of materials, six ferritic steels, and two austenitic steels. The seamless alloy-steel pipe specifications cover eight ferritic and four austenitic steels. The specifications provide that information on high-temperature data is to be a matter of agreement between the purchaser and seller until such time as the Committee's studies warrant the addition of an appendix giving data now being developed.

Tentative revisions have also been approved in the standard specifications for structural steel for ships, involving a reduction in maximum sulphur from 0·06 to 0·05, and a minimum elongation of 18% in material for ¾ in. in thickness. When these proposals are adopted as standard, the specifications will agree on these matters with the standards for bridge steel. Revisions also have been accepted as tentative in the standards for carbon-steel castings, alloy-steel bolting material, and pipe flanges, all for high-temperature service, providing additional data on the use of the materials in oil-refinery service.

Copper-Silicon Alloy Products,

Tentative specifications have also been approved covering (*a*) copper-silicon alloy plates and sheets, (*b*) sheet copper-silicon alloy, (*c*) copper-silicon alloy rods, bars and shapes. The three specifications have the same chemical composition requirements. This involves a silicon range of from 1 to 5%, and the following maximum percentages of the respective metals: Manganese, 1·50; zinc, 5·00; iron, 2·50; tin, 2·00; aluminium, 2·00; with copper, the remainder. In the case of the specifications for sheets which are commonly used for drawing, forming, stamping, and bending, the minimum tensile strength requirement in the case of soft material is 50,000 lb. per sq. in., with an elongation of 35% in 2 in. On half-hard material corresponding figures are 70,000 and 10%, while for hard material the minimum tensile strength is to be 80,000 lb. per sq. in., and elongation in 2 in. of 5%. The minimum tensile strength for the plates and sheets used for pressure vessels is 55,000 lb. per sq. in., yield point, 22,500 with minimum elongation in 2 in. of 40%, and in 8 in. of 25%.

There are varying requirements for the specifications covering copper-silicon alloy rods, bars and shapes, depending on the form of the material. The minimum tensile strength in the case of rods varies from 50,000 for soft material in all sizes to 90,000 lb. per sq. in. for hard material over ¼ in. to 1 in. inclusive in diameter. For bars, tensile strength ranges from 50,000 to 65,000 lb. per sq. in., while for shapes, soft temper, all sizes, the minimum tensile strength is 50,000 lb., but for hard temper, in all sizes, the physical requirements are to be matters of agreement between manufacturer and purchaser.

Tentative revisions have been approved for publication as tentative in the standard specifications covering steam or valve bronze sand castings, composition brass or ounce-metal sand castings, and sand castings of the alloy: copper, 88%; tin, 8%, zinc, 4%; while the standard specifications for the alloy: copper, 88%, tin, 10%; zinc, 2% have been withdrawn.

In line with reports of an investigation on the aluminium content of Alloy XXIII, covered in the specifications for zinc-base alloy die-castings, the maximum limit for aluminium has been lowered from 4·5 to 4·3%.

All of the above actions on standards were approved at the August meeting of the Committee on Standards, at which 17 new specifications and tests were accepted for publication as tentative.

ENAMELLING IRON

A review of the developments in the production of pure iron to meet the exacting needs of the enamelling industry was given by Mr. N. H. Oakley-Evans, at recent meetings of the Institute of Vitreous Enamellers, in which he discussed its history, applications, and characteristics, some extracts from which are given in this article.

THE demands of industry on steelmakers has involved exacting chemical research which has contributed greatly to the science of iron-making. The chemist learned to discern the affinity iron has for certain other elements, such as carbon, silicon, phosphorus, sulphur, copper, and manganese, and to understand the peculiarities possessed by iron when associated with these elements. After much experimental research he learned how and when to remove these impurities from iron in the open-hearth furnace in order to meet the need for large quantities of pure iron.

Although developed primarily to cope with the problem of corrosion, pure iron was soon recognised as an ideal base metal for the exacting requirements of the enamelling industry. The problems and needs of the enameller were studied with meticulous care by chemists and metallurgists, and eventually a special grade of material was evolved to satisfy the enamellers' demands, which include: Cleanliness of surface and structure; freedom from distortion; a surface capable of providing a tight bond with enamel; uniformity and consistency in quality; accuracy in gauge, size, and flatness; reliable welding properties; and deep drawing qualities.

Cleanliness in metal is imperative. Structurally, it must be sound and pure. A uniform ferrite structure is desirable, virtually without iron carbides, which are common to steel. For best results it is essential that a sound structure be accompanied by uniformly clean sheet surface, to avoid pitfalls in enamelling. Good surface is not only the result of sheet rolling, but is dependent upon exacting care being exercised throughout processing, from the ingot, to the final operation on the sheets.

Conditions of blooming and bar mills must be such that heavy scale, scabs, lapped bars, and rough edges are eliminated. The slabs must be carefully cropped to avoid lamination, which might occur from piped areas. At the hot mills, where the bars are reduced to sheets, heating again is a serious problem. Grease, heavy scaling, and inaccurate gauge are a few of the worries of the hot mill man. Contrasted with commodity mill floors, hot mill standings, where pure iron is made, must be immaculate; temperatures have to be carefully regulated and atmospheres clean and under strict control, otherwise prime quality cannot be obtained. Cleanliness must again be exercised in heat-treating, whether sheets are box annealed or normalised, temperatures pyrometrically controlled, and the fuel and furnace conditions such that proper reducing atmospheres obtain. Pickling operations also demand constant checks on temperatures, acid concentration and freedom from foreign matter, which might be detrimental to sheet surfaces.

Freedom from distortion or sagging is a characteristic which is largely dependent upon the purity of the metal. Inherently, a pure iron is homogeneous and free from localised segregations—consequently less prone to warp. Adequate annealing to relieve all rolling strains also helps in the attainment of flatness. The critical changing point in pure iron is higher than in the case of steel, consequently it can be annealed at higher temperatures than steel, with less structural disturbances than the latter.

Surface Condition.—A great deal of research has been conducted to determine the best type of sheet surface for vitreous enamelling metal. A happy medium must be found between a rough surface, from which defects may arise owing to scale or pits, and that of highly polished or cold-rolled surface, the slickness of which interferes with a satisfactory bond. Extreme smoothness of surface requires a very critical viscosity, or set up of the slip, in order to maintain the proper weight of enamel distributed uniformly over the sheet surface. It is extremely difficult with excessive smoothness of surface to prevent the so-called secondary drainage. With a properly cleaned and roughed sheet surface the ideal conditions exist for ease of control of enamel distribution on the sheet surface.

A matt-like surface is most desirable, which, under the microscope, shows minute tentacles which grip and bind the enamel coating to the base metal, forming a sound, solid foundation. Microscopic study has revealed that this type of surface, common to pure iron, is much more satisfactory from the standpoint of adhesion. Obviously, the most desirable condition consists in using a base metal and an enamel which develop the strongest possible adhesive forces.

Gauge Uniformity is also of importance to the enameller. Definite temperatures are, of course, established for various thicknesses, and consequently irregular results in the enamelling process would arise to some extent if gauge variation were unreasonable.

Another problem is the necessity of securing as many pieces of finished product per ton as possible, which only can be estimated accurately when material is carefully rolled to proper gauges. Obviously, the technique of gauge control is complicated by the inherent characteristics of hot mill practice. Compensations must be made for roll contour and for the spring in rolls. For these reasons it is necessary that commercial tolerances are allowed sheet producers and it is interesting to note that sheets are actually supplied to an allowable variation on standard 20-gauge material of plus or minus 3/1,000ths of an inch.

Welding.—So many enamelled products to-day are subjected to drawing and assembly by welding that it is of great importance for the base metal to be welded easily without blistering. Here, again, pure iron has proved in practice to be superior, as it lends itself admirably to a strong uniform weld, over which enamel coatings may be fused with scarcely a trace of the joint being discernible.

Drawing Properties.—Many products, such as signs, table tops, exterior stove and refrigerator panels, and the like, do not require particular drawing properties, but rather demand extreme flatness. There are, however, many applications to-day, such as refrigerator linings, oven doors, and a multitude of accessory parts, which definitely do necessitate material suitable for deep drawing work. In such cases, the metal must be treated specially, and the supplier can do this intelligently only with the help of blue prints or samples of the parts to be made.

For spinning and deep stamping best results are obtained with a normalised grain structure, which is smaller and more tenacious than that commonly obtained from box annealing. For instance, washing machines which, a few years ago, were formed by the use of box annealed material, requiring several drawing operations with intermediate annealing, are now made with only one drawing operation, and no annealing between the time the sheet leaves the suppliers' plant and the firing of the ground coat enamel.

This excellent drawing property has made possible

considerable saving by the elimination of many drawing processes and a number of annealing operations that were necessary previously. Sinks are now being formed commercially of pure iron, and many other uses will doubtless be found as a result of the excellent drawing properties which are now obtainable.

Modern Applications.—Holloware was, of course, one of the original and most common products of the early enamelling trade. However, experts have not tied themselves to the original manufacture of enamelled holloware, but during the last few years have searched for new applications. Vitreous enamelling is eminently desirable and practical where lasting durability, consistency of surface protection, attractiveness of colour, good appearance, and hygienic cleanliness are called for.

Enamel works which have been engaged with the manufacture of kitchenware and similar applications, are realising day by day the further possibilities that exist for enamelled products. To-day the kitchen is rare that does not boast of an enamelled table top, enamelled pots and pans, and, in the great majority of cases, it is also furnished with a sheet-iron enamelled stove, and possibly an enamelled refrigerator. Still there is an undeveloped realm in the household itself, where vitreous enamelled metal has not been exploited. The disagreeable old type of sink with wooden draining board is being replaced by a clean, seamless basin with an attractive enamelled draining board attached. In the bathroom, porcelain tiled walls could well give way to sheet iron vitreous enamelled tiles; and the bath tubs themselves, as well as washbasins, will unquestionably be made within the next few years of deep drawn metal, vitreous enamelled in attractive colours.

Drawn metal, which is light, strong, attractice, and economical, is, in many directions, replacing cast iron, particularly for sanitary applications, such as water-closet flush tanks, hot water tanks, geysers, etc., where cleanliness is important. In England at the present time, excellent progress is being made with the manufacture and sale of vitreous enamelled piping for interior and exterior drainage systems, as well as for roofing gutters, roofing tiles, and corrugated enamelled roofing.

Enamelling Problems.—Factors which may hamper, to some degree, the more extensive use of vitreous enamelling are the troubles which are commonly suffered in the application of a satisfactory enamel coating. It is only by pooling interests and by close co-operation that these problems can be solved by the joint efforts of iron-makers and enamellers.

Among difficulties which are not always traceable to the metal "copperheading" may be discussed. During the firing of the enamel, there is a normal oxidation of the metal surface before the enamel fuses. This oxidation is a result of the infiltration of air between the particles of the dried enamel coating. This oxidation begins as soon as the iron reaches sufficient temperature to oxidise, and continues until the enamel has fused. The amount of oxidation is governed by many conditions, such as rate of heating, furnace atmosphere, the metal used, gauge of metal, thickness of enamel coating, fineness of grinding, and so on.

It has been proved in our laboratories that "copperheading" is a result of oxidation of the metal in a local spot, so that excess iron oxide is produced at that spot. Under such a condition, a portion of the iron oxide dissolves in the enamel and during cooling may recrystallise in bronze or copper-coloured iron oxide crystals. There may occur all degrees of oxidation from just sufficient iron oxide to dissolve in the enamel and leave a slight depression or dark spot free from bubbles in the enamel, to a large excess of iron oxide, in which there is only scale covering the metal.

In the studies on "copperheading" of enamel, it has been noted that the metal is often blamed for the trouble, and that microscopic evidence has shown that actually the metal is rarely at fault. The oxidation of the meta surface in such cases shows only the roughened oxidise surface as a result of the cause of the "copperheading," but the metal itself exhibits no cause.

Similarly, "*fish-scaling*" of enamel has many cause. It is true that proper attachment of the enamel to th metal will usually prevent this trouble—however, the metal, though often blamed, may not be the inherent cause. The cleaning of the surface, the proper firing of the enamel, the proper range of expansion of the enamel, may all affect the strength of the attachment of metal and enamel and thus cause "fish-scaling." The chief causes of this defect which have been advanced are chemical balance of the enamel, improper smelting or milling, failure to stir liquid ground coat enamel frequently, improper pickling of iron, under-burning or over-burning, and leaky muffle furnaces.

Among other enamelling defects discussed that of blistering was included, but Mr. Oakley-Evans stated that while the sheet-metal manufacturer can contribute to a limitation of this defect by supplying uniformly clean, homogeneous iron, the majority of the causes were beyond his control. In conclusion, it was stated that enamelling iron is not a standardised product, but a carefully developed material to meet the specialised requirements of the enamelling industry. Consistently uniform satisfaction can only be given when the maker is in full possession of the enamellers' individual needs and changes which he makes from time to time.

New Deposits of Gallium.

LARGE deposits of gallium, a rare metal occurring chiefly in iron ore, have recently been discovered in the Altai district by an expedition headed by Academician Zvyagintsev, sent out from the Academy of Sciences of the U.S.S.R. The importance of gallium lies in the fact that it has a low melting point—30° C.,—while its boiling point is very high—1,600° C. This great interval between boiling and melting point makes gallium indispensable for high-temperature thermometers. The low melting point of gallium also renders it very useful for electrical installations, such as automatic fire signals, as it greatly increases their sensitivity. Another use for gallium has been recently found in the treatment of syphilis. Its prophylatic and healing qualities have proved to be superior to those of mercury and arsenic; while there is a complete absence of the harmful effects which frequently accompany the latter two.

About the year 1869 Mendeleev, the world-famous Russian chemist, on the basis of the periodic law of the elements predicted that such an element would be found, and gave it the name eka-aluminium. Six years later this element was discovered by a French scientist, Lecoq de Boisbaudran, who called it "gallium," in honour of his native country.

Gallium occurs very widely, but only in very minute quantities, which has hitherto made it extremely costly. It does not exceed 0.1 in the concentrations in which it% is found, and this renders it very difficult to obtain in a pure state. The expedition which found the deposits in the Altai district has worked out a method of obtaining gallium in a pure state which will considerably reduce its cost.

Zinc used in hot galvanizing baths should contain from 1 to 1·60% lead and 0·08% iron, according to practice followed by the British sheet galvanizing industry. Cadmium in small amounts sometimes is added to the bath, but this element tends to produce fine and small spangles. A bright metallic finish and good characteristic spangles are secured when the bath contains small quantities of aluminium and tin. Dull and brittle zinc coatings are caused by small quantities of antimony.

The Application of Anodised Aluminium and its Alloys

By G. O. Taylor.

The anodic oxidation process as a means of promoting decorative effects and at the same time of improving the corrosion resistance of aluminium and certain of its alloys, discussed in the last issue, has created much interest, and in this article the author describes the many fields in which this process is now being applied.

THE anodic oxidation process as a means of producing a hard corrosion-resisting oxide film on the surface of aluminium and certain of its alloys is now fairly well known, but the many and diverse uses of anodised material are not generally appreciated. Ten years ago the process was still in the experimental stages, and commercial anodising was practically unknown, but worldwide research has resulted in such rapid developments that hundreds of thousands of articles involving several thousands of tons of metal are now anodised every year.

Probably the first generally appreciated property of the anodic film was its exceptional resistance to corrosive action, particularly by the atmosphere and seawater, and it was in the direction of providing a corrosion-resisting surface for light alloy material that the process developed. The first extensive application of anodised aluminium was made by the aircraft industry to overcome corrosion difficulties and paint adherence problems encountered on aircraft incorporating light metal construction with alloys of the high strength heat treatable type which were found to suffer pitting and loss of strength on seaplanes and craft operating near the seaboard.

The value of the anodic oxidation process in providing a hard, passive surface coating, possessing excellent paint-bonding properties was soon realised, and some of the leading aircraft firms installed plants for the processing of the alloy parts. The treatment proved so successful in securing good paint adhesion and in preventing the intercrystalline type of corrosion, to which the heat-treatable alloys are susceptible, that anodic oxidation became increasingly employed. As a concrete instance, one well-known American firm has produced aircraft of all metal light-alloy construction, with both structural members and wing and fuselage sheathing anodisid, having the interior surfaces of the fuselage painted to prevent "sweating," but with the exterior fuselage and wing surfaces left unpainted in the natural grey of the oxide film with the production of a neat and pleasing appearance. This is not, of course, the usual aircraft practice, but it serves as an indication of the high degree of corrosion resistance conferred by anodic oxidation.

A variety of light alloy parts required to withstand severe marine conditions are anodised and give good service in applications for which the use of aluminium alloys was formerly regarded as unsuitable, but with the development of naturally corrosion resistant alloys specially suited for marine usage it is not so necessary to anodise to secure permanence of resistance except under extremely arduous conditions. Similarly the introduction of high strength aluminium-magnesium alloys and alloys of the Duralumin type protected by thin layers of pure aluminium integrally rolled into the surface, both of which offer in the normal condition even better corrosion-resisting properties than anodised Duralumin, may render the use of the process less necessary in the aircraft industry, although valuable as a means of securing paint adhesion. However, apart from this class of work, development of the anodic oxidation process has proceeded in many other ways.

The property of the anodic film of being able to absorb and retain colouring media and thus provide surface finishes both decorative and protective in effect has been exploited in the treatment of everyday domestic articles, such as serving trays, cups and saucers, plates, egg-cups, jugs, serviette rings and hot-water bottles, etc., which strike a clean and efficient note in even the most modern labout-saving kitchen. Mention may also be made of the increasing use of aluminium alloys for hospital utensils, which are anodised to provide a protective finish.

One American manufacturer has recently marketed large sheet metal mixing bowls having an attractive anodised frosted finish, and sold complete with a wooden spoon. The little touch of sales psychology in the provision of the wooden spoon merits attention. By this means does the enterprising manufacturer ensure that the housewife shall not use a metal spoon which might abrase and

The anodic film absorbs and retains colouring media and thus enables the use of finishes which are both decorativ. and protective; this property has been exploited in the treatment of everyday domestic articles and in the application of aluminium alloys for hospital utensils.

By Courtesy of the London Aluminium Co., Ltd.

damage the surface of the bowl! Another direction in which development may be expected is in the production of special vessels (having the base anodised and coloured with a heat-resisting black pigment) for electric hot-plate cooking. Such a black finish absorbs or radiates heat, and tests already carried out have shown that a vessel so treated will boil water in half of the time required to boil water in a similar vessel with a semi-bright finish.

The electrical industry provides several outlets for anodised metal. The oxide film possesses the peculiar property under certain conditions of passing current freely in one direction, while retarding the passage in the opposite direction, and this function has been utilised in the construction of rectifiers incorporating anodised aluminium plates for the conversion of alternating or direct current. Anodised plates are similarly employed in certain types of lightning arresters where, when a certain potential is attained, the insulation afforded by the oxide film breaks down, and the accumulated charge is released to earth, the film then automatically resealing till the

breakdown potential is again reached. The insulating propetty of the anodic film is being able to withstand quite considerable voltages without leakage is also being investigated in connection with coil equipment for various types of electrical apparatus, since the space between the turns, usually occupied by bulky insulating material, can either be dispensed with or utilised by winding in extra turns, so that it is possible to produce smaller coils for given values, or coils of greater values for a given size.

Electric-light fittings in both wrought and cast material anodised to give various pleasing finishes, are a welcome change from the standardised bronze, moulded, or chromium-plated fittings, and harmonise well with furnishing schemes in the modern note. Such fittings are especially useful for ships' cabin work, as they require little or no maintenance, and are not subject to the discolouration of bronze or the peeling of chromium plate.

A recent development is in the comemrcial production of aluminium reflectors subjected first to an electrolytic brightening treatment and then anodised to produce a tough practically transparent oxide film to afford protection against atmospheric tarnishing. These reflectors are available either polished for focussed reflection or with a bright matt surface for diffused reflection as for floodlights. Field tests recently carried out with this type of reflector and the ordinary type for several months in the open air showed that, while the unprotected material lost a considerable percentage of reflective efficiency through atmospheric tarnishing, the anodised metal was practically unimpaired, and the full efficiency could be restored by simple cleaning. This type of reflector also has the advantage that where cleaning is necessary to remove collected dust, etc., this can be quickly and easily done without damage to the surface, whereas the softer surface of an ordinary reflector might suffer abrasion.

In the automobile industry small parts have been anodised to secure hardness for wear resistance, and, in cases of special service vehicles required to operate in districts where the water supply is of a hard and corrosive nature, alloy parts of the water-circulating system have been treated to obtain protection against corrosion.

The use of light alloy parts in the cycle industry is not at present extensive, but anodised handle-bars and seat pillars in both plain and coloured finishes have been available for some time. A logical development here would be the introduction of light-alloy mudguards with an anodised bright matt finish, to meet the present demands for lighter weight construction and visibility after dark.

The remarkable versatility of surface finishes abtainable by anodising has resulted in the application of aluminium to the production of many novelties. In America, particularly, anodised material has been used for the making of powder compacts, cases, trinket caskets, bangles, expanding bracelets and vanity bags of chain mesh, and the novel appearance of the articles has there produced sales sufficient to warrant commercial production.

Chemical manufactvrers handling products in aluminium vessels and trays have found the process useful for providing their equipment with a hard corrosion-resisting surface, particularly in the case of crystallising trays for the production of high-purity crystals free from metallic contamination. Such anodised articles have a long, useful life, since, at the first signs of surface attack, they can be re-anodised for a further lease of service at a small cost. The smooth, hard surface also renders equipment easily cleanable and more hygienic for foodstuffs preparation.

A more intimate field offering extensive ground for future development, and in which progress is rapidly being made in the application of light alloys, is in the building and allied industries, the modern demand for clean, "white" metals requiring little maintenance, attention being admirably met by anodised material. In this connection however it must be remembered that architectural metalwork is frequently exposed under rigorous conditions, and that to ensure permanent good appearance the alloy material itself must be of high corrosion-resisting properties. In view of this, therefore, the majority of the work carried out up to the present has been in one or two alloy materials only, mostly in the alloys of the aluminium-magnesium series. An interesting use of anodised material in this connection is for strips holding on the glass frontage of buildings of ultra-modern type, such as the *Daily Express* Building, Fleet Street, London, where the black glass exterior wall covering is secured by extruded aluminium-magnesium alloy strips anodised to a silver finish. Lever handles, door pulls, finger-plates, kicking plates, light fittings, ornamental grilles, nameplates, decorative metal strips and shop fittings are other instances of applications which come readily to mind.

As a final example of the astonishing diversity of the use of anodised material, it is of interest that it has recently been found that the oxide film will absorb and retain light-sensitive chemicals, with the result that thin sheets of aluminium are now the basis of a process for photographic reproduction.

Specifications and Tests for Coal and Coke.

For the first time a compilation of all the standard and tentative specifications and tests for coal and coke, as issued by the American Society for Testing Materials, has been published. This includes five specifications, 13 methods of test and the standard definitions of terms relating to coal and coke. Foundry coke and gas and coking coals are covered by specifications, and to make the pamphlet complete the recently approved requirements for classification of coal by rank and by grade, developed by the Sectional Committee on Classification of Coals, are included.

One of the important activities of A.S.T.M. Committee, dealing with coal and coke, is the development of satisfaction sampling procedures. In this compilation are given the methods of laboratory sampling and analysis of coal and coke, and procedure for sampling coal; also sampling coke for analysis. The standard tests for the cubic foot weight of coke and of crushed bituminous coal are included, as well as the methods of sieve analysis of these products, and tests for the fineness of powdered coal. The shatter and tumbler tests for coke are detailed; also the method of determining volume of cell space of lump coke and testing for size of anthracite. An important test for the agglutinating value of coal, issued in the form of a proposed draft, is given.

Copies of this publication, aggregating 108 pages in heavy paper cover, can be obtained from A.S.T.M., 260, South Broad Street, Philadelphia, at \$1·00 each. On orders for 10 or more copies special prices are in effect.

A Reflectivity Method for Measuring the Tarnishing of Highly-Polished Metals.

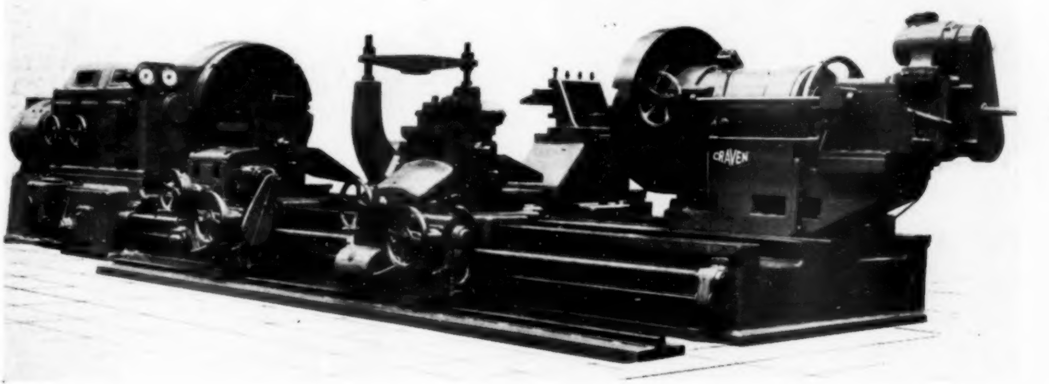
This paper by Messrs. L. Kenworthy and J. M. Waldram, describes an apparatus and method for carrying out the quantitative assessment of tarnish on highly-polished metals, by reflectivity measurements. The method involves the separate determinations of the specular and diffuse components of reflection, and the use of an empirical formula combining these two properties. The application and validity of the method are illustrated by the results of periodical measurements, and observations made on specimens of pure tin and two tin alloys exposed to indoor and outdoor atmospheres.

It has been reprinted from *The Journal of the Institute of Metals*, and is contained in a recent publication issued by the International Tin Research and Development Council, copies of which are available on application to the offices of the Council Mansfield House, 378, Strand, London, W.C. 2.

The Machine Tool Exhibition

The development of machine shop methods and advances in the manufacture of cutting tools have stimulated progress in machine tool design. The designer is making greater use of the superior structural materials now available to provide the degree of rigidity, strength and fatigue resistance properties necessary for modern machine tools. Ample evidence of this progress is available at Olympia, where manufacturers are exhibiting their latest products.

THE progress made in the development of high-duty alloys, and the need for increased speed of production has necessitated considerable research with a view to improving high-speed steel and other cutting materials of an exceptional character and also the development of suitable technique to obtain the best results. At the last Machine Tool Exhibition, held in 1928, it was demonstrated that considerable success had been achieved in improving the cutting qualities of various materials, but it was found that the higher cutting speeds and heavier feeds, necessary to obtain full advantage from the new cutting materials, imposed duties on many machines that they were never designed to bear. Since that time, however, there has been remarkable progress in the design and construction of machine tools and the Exhibition now being held at Olympia is an encouraging sign of this progress. Practically every British machine tool maker is represented and has something new to show. In addition to British machine tools there are many German, American and Swiss machines which make the Exhibition fully representative and of an international character.



Showing the extraordinary massive construction of the roll-turning lathe exhibited by Messrs. Craven Brothers Ltd.

While the important advances made in the manufacture of cutting tools have stimulated progress in machine tool design, the development of machine shop production methods have had considerable influence. The designer has been assisted by developments in other branches of industry. He has been able to draw upon superior materials for structural purposes and, as the exhibits show, developments in the electric drive have been incorporated to a very great extent, and the employment of multi-speed motors as well as reversing motors is making much headway.

For structural purposes the machine tool designer is able to draw upon a wider range of materials than formerly, and in order to obtain the requisite degree of rigidity combined with strength and fatique-resistance properties, he is making greater use of alloy steels and alloy cast iron.

Although many materials show an ultimate strength superior to cast iron, this material possesses certain definite advantages for machine tool construction. It has been found, therefore, that modern demands are more satisfactorily met by the use of improved cast irons rather than by the consideration of alternative materials. The better service obtained from alloy cast irons, as a result of their higher strength, better wearing qualities and finer finish, has enabled manufacturers to meet modern service conditions. In the construction of the smaller parts the use of alloy steels is becoming increasingly necessary to resist the high stresses modern machine tools must bear.

In addition to those machine tools that function with cutting tools, similar progress has been made in machines designed for finishing work by grinding, lapping and honing. There is evidence that permissible limits are becoming more exacting and increasing the use of these machines. Here, too, the need for improved materials has been realised, especially with grinding machines, which impose considerable abrasive action on certain parts and render their serviceable life very short unless suitable material is employed. For instance, the supporting blades in centreless grinders have long been a problem, because of the combined abrasive action of the work and the grinding medium. As a result of prolonged investigations, two types of blades have been developed, the analyses of which are as follows :

	Total Carbon.	Silicon.	Nickel.	Chromium.	Brinell Hardness.	Heat Treatment.
1	3·6 to 3·7	1·05 to 1·15	3·75 to 4·0	1·00 to 1·10	402 to 444	O.Q.1420° F. Draw 300° F.
2	3·25 to 3·35	1·10 to 1·20	4·25 to 4·50	1·65 to 1·75	578 to 652	None.

The adoption of support blades composed of alloy cast iron of these types has eliminated, to a considerable degree, the annoyance and delay of replacing worn supports while affecting an important ultimate economy in material costs.

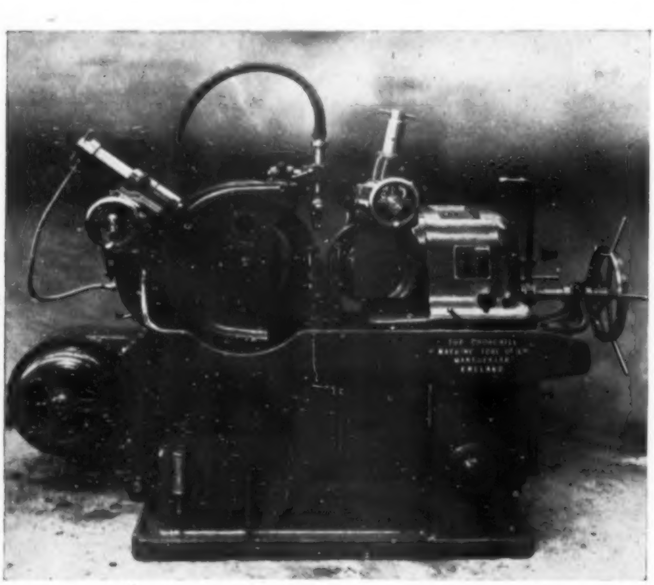
With high grade materials and improved design it is not surprising that the exhibits at Olympia show great changes in comparison with the last exhibition. It is not possible to describe all the developments which are represented in the exhibits, but in the following notes brief reference will be made to some outstanding features at this Exhibition.

Some Machine Tools.

In such a comprehensive exhibition of machine tools, it is difficult to single out any special machine without making reference to the exhibits of each manufacturer,

but the 30 in. "Craven" roll turning lathe is of special interest, because of its extraordinary rigid and massive construction. It is designed for turning rolls up to 16 ft. 0 in. in length and 45 in. diameter on the body for the tinplate trade. Roll turning is demonstrated with this machine at the Exhibition. The roll to be turned, is held by both wobbler ends in powerful chucks, and both the roll body and the journals may be turned at one chucking. The machine is specially designed for the use of tungsten carbide tools, and the in-feed and adjustment of the tools is by screw motion. It has two front slides and one rear slide, which latter has feed in the transverse direction only and hand adjustment longitudinally. One of the front slides has a cambering apparatus which automatically produces any desired camber, either convex or concave, on the body of the roll.

This machine is only one of a large number exhibited by Messrs. Craven Brothers, which include five types of milling machines; a 24 in. centre heavy duty high speed



One of two centreless grinders exhibited by the Churchill Machine Tool Co., Ltd.

sliding, surfacing, taper turning and screw cutting lathe; a 4 ft. 0 in. carriage and wagon heavy duty wheel lathe; a 15½ in. centre double ended axle finishing lathe; a 52 in. vertical turret lathe; an automatic spline slotting machine, for slotting internal splines; a slot "Hydromil," and a 9½ in. centre motor car crankpin turning lathe. In addition, a precision roll grinding machine is displayed suitable for the tinplate trade and capable of accommodating rolls up to 40 in. diameter. It is noteworthy that this latter machine was sold to The Baglan Bay Tinplate Co., Ltd. This machine may be used for grinding new rolls or for re-surfacing used rolls, and, if the special chamfer grinding rest is fitted, a roll can be completely finished at one setting.

A very wide range of machine tools is exhibited by Messrs. Alfred Herbert Ltd. One of the most interesting is the No. 22 combinat on turret lathe, which has been specially designed for the heavier classes of turret lathe work. It is new throughout and has many features that enable it to produce such work accurately and quickly and with the least possible fatigue to the operator. The maximum swing over the bed covers of this machine is 28 in., but, if required for special work, the lathe can be supplied with centres raised which enable a maximum swing of 33½ in. over the bed covers. Among the many machines exhibited by this firm are a few American machines of outstanding merit, one of these being an internal grinder operated on the centreless principle. It is built to the design of The Heald Machine Company, and is claimed to have created a new process. The outside diameter of the work is used to generate a path for grinding the bore. In the design and construction of the machine itself there have been included many important refinements and features. In addition to its being fully automatic, there is a complete hydraulic control throughout and it can be furnished with either the Size-Matic or Gage-Matic principle of automatic sizing depending on the work to be ground.

Another example of American machine tool design on Herbert's stand is a hydraulic, double head crankshaft pin grinding machine that has been built to meet the needs of motor car manufacturers. A noteworthy addition to the Herbert range is a universal milling machine which embodies every feature that Herbert's have found of value in their long experience in building universal milling machines, and in using them in their extensive tool room. This machine is a self-contained unit driven by its own motors, and has an unusually wide range of spindle speeds and feeds, with power traverse to the motions of the table.

A comprehensive range of precision grinding machines is exhibited by Churchill Machine Tool Co., Ltd. Noteworthy of these are two centreless grinders, one arranged for through feed grinding, and the other for concentric grinding. The through feed method is applicable to a large variety of straight parallel work, such as rollers and gudgeon pins, etc. The patent through feed work rest enables full advantage to be taken of the high productive capacity of the machine when handlining small batches of components. Thes rest can be set up from one size of component to another merely by swivelling the blade, this operation being facilitated by a protractor, and by adjusting the space between the grinding and control wheels. Complete re-setting can be carried out in less than three minutes. An outstanding feature of this exhibit is the patent "Hydrauto" grinding wheelhead which is also applied to other models exhibited by this firm. Another interesting Churchill machine is an automatic internal grinder. The insertion and removal of the work are the only operations manually performed, after starting this machine. Bores are ground by the "Plunge Cur" method, movement of the table when grinding being a high speed oscillation. The maximum length of the oscillation stroke is ¼ in. The machine will operate on taper bores and a special feature is that it can be equipped to perform face grinding operations at the same setting as the grinding of the bores.

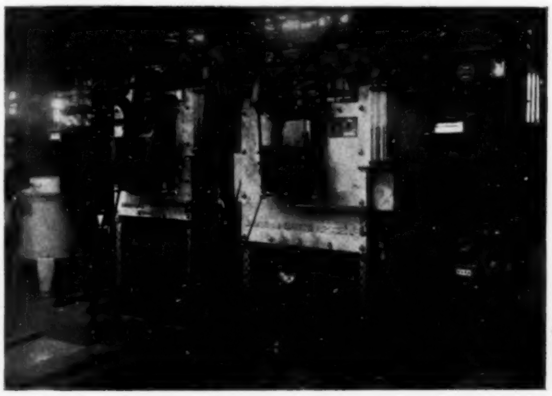
Messrs. John Stirk and Sons, Ltd., although unable to examples of all the "Hiloplane" family, especially as they are now making double housing machines over 12 ft. 6 in. wide, and single column machines with up to 10 ft. 6 in. reach, but three representative machines are shown in the openside "Hiloplane," and two double housing planers known as the "Hiloplow" and "Ingoplow" respectively. The "Hiloplane" is demonstrated cutting at over 300 ft. per minute, with a quick return. The transmission is by keyless helical driving gears and rack and electro-magnetic tool lifters are fitted. The "Ingoplow" is specially designed for machining extra hard ingots and similar type of work. It is shown taking heavy cuts at slow and moderate speeds. The transmission is by means of heavy keyless spur gears and rack.

The opensided vertical and horizontal milling machine, shown by Messrs. Kendall and Gent, represents a further addition to a wide range of these machines by this progressive firm. It has been designed to accommodate all classes of work. A special feature in this machine is the control gear. The motors for the drive and feed motions are electrically interlocked, so that failure of the spindle driving motor causes the saddle and table feeds to be put out of action instantly. The machine is arranged for feeds of 1 in. to 12 in. per minute in nine changes to each spindle speed. This firms latest plans milling machine is also on view together with a range of screwing machines of an outstanding character.

One of the most comprehensive exhibits is that of Messrs. A. C. Wickman Ltd. Some 30 machines are on view, including the new Wickman-Lang ⅝ in. single spindle auto. This machine is designed for the automatic production of screws, studs and other plain components from bar material, and can also be used with advantage as an automatic cutting-off machine. It is of simple and rigid design, and its versatility is a feature. Two machines are on view, one producing a brass component at the production time of one second.

Heat-treatment Furnaces.

Associated with the display by Messrs. A. C. Wickman Ltd., is a series of furnaces by Birmingham Electric Furnaces Ltd. These include the forced air circulation furnace for secondary hardening high speed steel, tempering, etc. ; a furnace designed for preheating high-speed steel, equipped with "Certain Curtain" atmosphere control; and a furnace for high-speed steel, brazing tungsten carbide tips, etc., also with "Certain Curtain" atmosphere control. The atmosphere control equipment is an important development by means of which scaling, pitting, de-carburisation, etc., is avoided, thus reducing or even eliminating the necessity of grinding tools after hardening.



The furnaces shown by Birmingham Electric Furnaces, Ltd., reading from left to right, are as follows :—
Model J F C.—Forced-air circulation furnace for secondary hardening high-speed steel, tempering, etc.
Model S A.20.—Furnace for pre-heating high-speed steel, hardening carbon steel, etc., with "Certain Curtain" atmosphere control.
Model H S.20.—Furnace for hardening high-speed steel, brazing Tungsten carbide tips, etc., also with "Certain Curtain" atmosphere control.

Amongst the furnaces in operation, the patent "Heavy Hairpin" box type furnace by Wild-Barfield Furnaces Ltd., has a special interest for those engaged in the heat-treatment of ferrous and non-ferrous materials. The exhibits of this firm also include toolroom tempering equipment, which is in operation daily; high temperature furnaces for high-speed steel treatment; a full range of muffle furnaces; and a forced circulating furnace. Since the introduction of the latter type of furnace, experimental work has been in progress to improve still further the air circulation. The results are incorporated in the Furnace shown, which has an output 25% higher than those previously obtained.

Complete heat-treatment equipment and accessories are exhibited by Kasenit Ltd., which includes a single-chambered electric furnace, gas-fired and electric salt bath furnaces, case-hardening compounds, molten carbon salts, anti-cementite, case-hardening boxes and pots, and quenching oil. The electric furnace is of new design, and is suitable for all temperatures up to 1200° C., particularly for tool rooms. It is heated by means of a number of Silit rods fixed underneath the floor, and on the crown of the heating chamber. These elements are so fixed that, in case of renewal, no disturbance of the brickwork is necessary. This furnace is a complete unit in itself, comprising regulating, resistance, ampmeter, voltmeter, and pyrometer. It is of excellent design, and in operation has considerable merit. The salt bath furnaces, which are designed for temperatures up to 1,000° C., fill an important need, and are a form of equipment which is being gradually appreciated. This firm demonstrate the recently-developed case-hardening compound, "Durapid," which, by reducing the time of treatment, effects considerable saving in case-hardening costs.

Brayshaw Furnaces and Tools Ltd. exhibit a number of furnaces which consist mainly of small units to show the principles employed in the construction of furnaces of larger size. The exhibit includes two oven furnaces, one natural draught type and the other the "Lopress" type, using fan pressure air with novel recuperative system. Two twin chambered high-speed steel hardening furnaces and two salt bath furnaces are also included, one of the salt bath furnaces is of the universal type, complete with automatic stirrer, air-gas proportioning valve and pre-heating chamber. Several interest furnaces are also exhibited by Lucas Furnaces Ltd., while a forging furnace by B. and S. Massey Ltd., is attracting much attention.

Engineers' Small Tools.

A very full range of engineers small tools is exhibited, including high-speed steel and tipped tools, twist drills, milling cutters of all types, reamers, metal slitting saws, end mills, broaches, tapping attachments, oil and suds pumps, machine vices, jigs and fixtures, accurate machined parts. A representative range of drill chucks, both key operated and keyless types are shown and demonstrated. Tapping attachments in various sizes are also demonstrated, including a small size for use in the electrical and radio trades, having a capacity for work from $\frac{1}{16}$ in. to $\frac{3}{16}$ in. Whitworth. Such firms as Arthur Balfour and Co., Ltd., Samuel Osborn and Co., Ltd., Edgar Allen and Co., Ltd., Thos. Firth and John Brown Ltd., represent only a few of the responsible firms showing tools covering a wide range of applications.

Two Wild-Barfield forced-air circulating furnaces installed in the works of a bearing manufacturer.

Grinding Wheels.

A large range in variety, size, shape and type of grinding wheels and abrasive products is exhibited by The Carborundum Company Ltd. The main display includes 10 units, which embrace the type of grinding covered by centreless grinding; surface grinding; gear, spline, and thread grinding; crankshaft and cam-shaft grinding; fettling; roll grinding; toolroom grinding, and grinding and burning of cemented tungsten carbide; internal cylinder grinding and honing; general cylindrical grinding; and special purpose grinding. Each unit is self-contained and specially designed to display to the best

(Continued on page 22)

Metallurgical Applications of Silicon

By J. W. Donaldson, D.Sc.

Formerly considered as an impurity in metals and alloys, investigations during recent years have shown that silicon used as an alloying metal has special uses, and in this article its application in steels, cast irons, corrosion-resisting alloys, aluminium alloys and bronzes is discussed.

SILICON is not a metal which can be used in its elementary state. In its purest commercial form, it is hard and brittle, and can neither be worked hot nor cold. It occurs as an impurity in many metals and alloys. Commercially, pure aluminium contains it in proportions up to 0·5%. In most carbon and alloy steels it varies from a trace to 0·25%. In cast iron, where the indirect effect of silicon has a marked influence on the properties of the iron, it may vary from 0·5 to 3·0% according to the type of iron required.

The use of silicon as an alloying metal was not considered of metallurgical importance until recent years.

By Courtesy of Messrs. Hadfield Ltd.
Original small transformer made in 1903.

This large transformer, without tank or oil weighs 19 tons, and contains 12½ tons of special silicon steel. The energy losses due to magnetic hysteresis and eddy currents are only one quarter those which would result from the use of the best iron known prior to the Hadfield invention of silicon steel.

It was generally looked upon as an impurity, and in some cases as a very undesirable impurity. The investigations of Hadfield and others on the silicon steels; the researches of Gwyer and Phillips, Otani, Petit, Archer and Kempf and others on the aluminium-silicon alloys; the work of Corson on the iron-silicon alloys; of Norbury and Morgan on the alloys of carbon, iron and silicon; and of Corson on the influence of silicon on copper, have led to the development of many alloys of industrial importance. Among these may be mentioned the silicon steels, high-silicon cast irons, corrosion-resisting iron silicon alloys, the aluminium-silicon alloys, and the silicon bronzes.

Silicon Steels.

Silicon steel has been used for many years for structural and electrical purposes. In 1889 Hadfield showed that the addition of 2% of silicon to a 0·2% carbon steel increased the tensile strength and the yield point without reducing the ductility. Work by subsequent investigators confirmed this, and as the result of the tendency during recent years in structural work to replace mild steels by steels of higher tensile strength, silicon steels or silico-manganese steels have been used for such purposes. This has been particularly the case in Germany, where much use has been made of a steel known as Freund or "F" steel containing about 0·1% carbon, 0·5% to 1·5% silicon and 0·6 to 1·5% manganese, and having a tensile strength of 30 to 35 tons per sq. in. Steels of similar composition have also been widely used in the United States. For the manufacture of springs, steels containing 1 to 1.5% silicon and 1 to 2% manganese have been found to give satisfaction.

The greatest economic value of silicon steel, however, is in its use as a core material for electrical apparatus, particularly for transformers. Steels containing approximately 4% silicon have a low magnetic hysteresis, high electrical resistivity, and good magnetic permeability. The beneficial effect of silicon on the magnetic properties is generally considered to be due to the action of silicon in limiting the solubility of iron for carbon resulting in the elimination of the gamma transformation, and in its action in promoting grain growth, as grain size is the governing factor in determining the magnetic hysteresis loss in finished sheets. Considerable care has to be taken, therefore, in the manufacture of such steels to ensure that the correct grain size is obtained, and as hysteresis losses are sensitive to mechanical strain annealing at various stages of the rolling is a necessity, in order to remove all such strains.

Iron-silicon Alloys.

The corrosion resistance of iron-silicon alloys containing 13 to 17% silicon is of great importance to the chemical industries for the construction of plant. They possess excellent corrosion resisting properties in withstanding the attacks of nitric, sulphuric, and acetic acids, either concentrated or dilute. They are liable to attack, however, by hot concentrated hydrochloric acid, unless they contain about 4% of molybdenum.

These alloys are close grained, hard and brittle, and extremely difficult to machine. They are usually finished by grinding, and take on and retain a high polish. As silicon-iron alloys are generally considered to be unworkable either hot or cold, they are usually used in the form of castings. Corson has shown, however, that by suitable heat-treatment, whereby the material is brought into a homogenous condition, it is possible to forge alloys condition, it is possible to forge alloys containing up to 14·3% silicon at between 1,050 and 1,200° C.

The physical properties of the iron-silicon alloys are poor, but they are sufficient for the purpose for which such alloys are used, provided they are not subjected to shock. The tensile strength of a silicon-iron alloy for chemical ware is approximately 4·5 tons per sq. in. with a resistance to compression of about 32 tons per sq. in. The thermal conductivity is about 10 times that of earthenware, so that chemical processes in high silicon alloy vessels are accelerated considerably.

High-silicon-iron alloys are made under trade names, such as Corrosiron, Duriron, Elianite, Tantiron, and Thermisilid, and the alloy containing molybdenum is known as Durichlor. They are used for the manufacture of such parts of chemical plant as condensers, pumps, baths, pipes and fittings.

High Silicon Cast Irons.

In ordinary grey cast iron, the lower the silicon content, the better are the heat-resisting properties of the iron. Investigations have shown that for engineering castings in which growth and volume changes have to be reduced to a minimum and which must withstand pressure, cast iron should have an all-pearlitic structure, with finely-divided, well-distributed graphite. To produce such irons, it is necessary to adjust the total carbon and silicon contents, keeping the silicon below 1·1%, and to regulate the casting temperatures and rates of cooling.

In 1928, as the result of investigations carried out by the British Cast Iron Research Association, it was found that by increasing the silicon content above 4%, volume changes diminish considerably at temperatures between 600 and 1,000° C., and were appreciably less than the changes in low silicon irons ar similar temperatures. A new series of heat-resisting irons were therefore developed under the trade name of Silal.

Silal irons contain from 5 to 7% silicon with 2.8 to 2.4% carbon. Their normal structure consists of ferrite and fine graphite in marked contrast to the pearlite-fine-graphite structure of low silicon irons. When such a structure is heated, there is no decomposition of pearlite, and consequently no change in volume, and fine graphite does not allow oxidising gases to penetrate into the interior. The high silicon content also increases the resistance of the material to scaling. Silal irons have a low tensile strength, when compared with ordinary cast iron, and are liable to crack on sudden heating and cooling. The addition of 18% of nickel and 2% of chromium to an iron containing 6% of silicon, and 1·8% of carbon increases its strength and resistance to cracking. Such an iron has an austenitic structure with fine graphite, and is known as Nicrosilal. In addition to having good heat-resistance properties, it resists corrosion well, is non-magnetic, has a high electrical resistance, and machines well.

Silal and Nicrosilal irons are not used for engineering castings for prime movers, where strength is required. For parts, however, where strength is not essential, and which are continually being replaced due to growth and scaling, their use is extremely suitable. Such parts are furnace castings, melting pots, retorts, firebars, and stoker links.

Silicon-aluminium Alloys.

Silicon is not a metal which serves as a basis for light alloys, but alloyed with aluminium, it has, during recent years, helped in the production of a very large number of industrial light alloys. Owing to the fact that silicon forms complex aluminium-iron-silicon compounds readily, pure silicon low in iron is added to many aluminium alloys in order to render the iron present less harmful by combining with it. In other aluminium alloys silicon in combination with magnesium forms magnesium silicine, which on precipitation during ageing produces hardening. Alloys of this type include Duralumin containing 0·5% magnesium, 0·25 to 0·3% silicon; "Y" alloy containing 1·5% magnesium, 0·3% silicon, and the Hiduminium "R R" alloys containing 0·1 to 5·0% magnesium, 0·2 to 5% silicon. Sand and chill cast alloys and die-casting alloys with good mechanical properties are also produced, containing approximately 5% silicon in which small proportions of copper may also be present.

The principal application of silicon in light alloys, however, is the production of alloys containing 9 to 14% silicon. Silicon-aluminium alloys within this range are extremely useful in engineering, and have become very important within recent years. These alloys have resulted from the discovery of Pacz and the subsequent work of others on the modification of silicon-aluminium alloys. When correctly prepared, these alloys have good foundry characteristics and many desirable properties. A binary alloy containing 12 to 13% silicon is tough, strong, and ductile, having a tensile strength of 9 to 10 tons per sq. in. with 5% elongation when sand cast, and 14 to 15 tons per sq. in. with 10% elongation when chill cast. Alloys of this type have also a good resistance to corrosion, particularly corrosion under marine condition, and are therefore being increasingly used in marine engineering and shipbuilding. They are manufactured under such trade names as Alpax, Silumin, M.V. "C," and Willmill.

Attempts have been made recently to improve the properties of these 12 to 13% silicon alloys by the addition of other metals, such as copper, manganese, magnesium, and nickel. Although certain additions are harmful to the physical properties, and interfere with the structural modifications, special alloys of this type have been produced with enhanced properties. Among such ternary alloys, all of which contain 13 to 14% silicon, may be mentioned Birmasil with 2 to 3·5% nickel; Lo-Ex with 2% nickel, 1% copper, 1% magnesium; Silumin-gamma with 0/3 to 0·5% manganese and 0·5% magnesium; and Wilmill "M."

Nicrosilal salt baths for containing molten salts.

By Courtesy of Sheepbridge Stokes Centrifugal Castings Ltd.

Silal oil engine ignition bulbs.

Commercial silicon-aluminium alloys with silicon contents of over 14% silicon, are now being produced, and are finding commercial application in the manufacture of aluminium pistons. Such alloys are usually referred to as the hypoeutectic aluminium-silicon alloys, and have a structure consisting of large plates of graphitoidal silicon in an aluminium-silicon eutectic ground mass. This structure is characteristic of white bearing metals, and has good sliding properties. The coefficients of linear expansion of these alloys are low, varying from 18·5 by 10^{-6} for alloys containing 22% silicon to 13·5 by 10^{-6} for alloys containing 35% silicon, which renders them particularly suitable for piston material. High silicon aluminium alloys are of necessity die-casting alloys, and are very difficult to machine. Their use is limited, but the 20% silicon alloys are being used in Britain in fairly large quantities, and in France a 25% silicon aluminium alloy is in common use, and experiments have been made with a specially-treated material containing 35% silicon. These alloys are produced under various trade names, such as Alusil, Supra, and Alsia. Alusil contains 21 to 23% silicon, 1% copper, and 0·3 to 1·0% iron and Supra 20 to 22% silicon, 4 to 5% copper, 1·5 to 2·0% manganese, and 0·3 to 1·0% iron.

Copper-silicon Alloys.

The value of silicon as an alloying element in copper alloys has recently been the subject of many investigations, and as a result a number of copper rich alloys, containing approximately 4% of silicon with or without other metals are now of industrial importance. Such alloys are generally known as the silicon-bronzes.

In the silicon-bronzes silicon is added to copper to replace tin, and 4% of silicon is found to have a hardening effect equal to 10% of tin. The other metals added are either zinc, manganese, iron, or nickel. These bronzes in their cast condition, have an improved strength and hardness, when compared with Admiralty gunmetal, and are equally resistant to corrosion. They can also be worked hot or cold An alloy containing 3 to 4% of silicon, 1·5 to 2·0% of zinc, and 0·5% of tin has a tensile strength as cast of 20 to 24 tons per sq. in., and after cold working this strength is increased to approximately 40 tons per sq. in. Annealing at about 300° C. after cold working not only relieves internal stress, but increases the strength and hardness due to a precipitation hardening effect. The electrical properties of these alloys are also good. The silicon-bronzes are manufactured under various trade names, such as P.M.G. Metal containing 4% silicon, 2% zinc; Everdur containing 3 to 4% silicon and 1% manganese, and Herculoy containing 3·25% silicon, 1·5% zinc, 0·5% tin.

Other copper alloys containing silicon are the silicon-brasses. The industrially important alloys of this type contain 4 to 5% silicon and 8 to 14% zinc. These alloys give good sand and chill castings, have good mechanical properties, which are improved by hot working, and are used for a variety of purposes. They are also produced under various trade names.

Interesting results have also been obtained by Corson in the heat-treatment and age-hardening of certain ternary copper-rich alloys containing silicon. These alloys which are known as the Corson alloys, contain 91 to 99% copper with a small addition of silicon, and one or other of the metals cobalt, chromium, iron, or nickel, in such quantity as to form silicides, and it is the precipitation of these metallic silicides which produces hardening after-treatment. Alloys of this type have good physical and mechanical properties, and are capable of being worked into a variety of shapes.

Silicon-nickel Alloys.

Silicon has also been added to nickel coppy alloys of the Monel ratio 70 nickel to 30 copper in proportions up to 3%, and have given alloys, which after heat-treatment, have a tensile strength of 40 to 50 tons per sq. in. with an elongation of 15 to 25%, and a Brinell hardness of 220 to 260%. These alloys resist corrosion well, and are also suited for parts subjected to severe abrasion. Added direct to nickel, silicon has a hardening effect, ad gives alloys very resistant to corrosion, but so far such alloys have not been developed industrially.

MACHINE TOOL EXHIBITION

(Continued from page 19)

advantage a representative range of standard brand grinding wheels as used on the most widely known and modern types of British, American and Continental grinding machines, together with a display of a variety of interesting work examples. Each unit is also equipped with a continuous cinema projector showing a three-minute picture, devoted separately to examples of typical grinding operations. A comprehensive range of Norton grinding wheels, made at the new works of the Norton Grinding Wheel Co., Ltd., is also displayed.

Ball and Roller Bearings.

Ball and roller bearings play an important part in the successful operation of machine tools, and the exhibits of Ransome and Marles Bearing Co., Ltd., The Skefko Ball Bearing Co., Ltd., and British Timken Ltd., show the development achieved in the application of ball and roller bearings. Each firm show special types which they have developed and show many applications necessitated by the advance towards higher speeds for all machine tool spindles. It is noteworthy that double-row double-purpose bearings are being applied. These have two rows of balls running in separate tracks, their usefulness where combined journal and thrust load are present is wide and varied.

Forging Machines and Presses.

Greenwood and Batley Ltd., show a number of interesting machines, including a ⅝ in. solid die, double-stroke cold forging machine; a ⅝ in. automatic bolt head trimming machine, and a 5/16 in. automatic screw thread rolling machine; a 1 in. vertical lead tube extruding press of the semi-automatic toggle operated type, extruding tin-coated lead or plain lead tubes. The cold forging machine is shown producing ⅜ in. B.S.F. cheese head bolt blanks, 1⅞ in. shanks, direct from a coil of ·375 in. diameter. Steel wire, having a strength of 30/35 tons per sq. in. tensile. Driven with a "Greenbat" 10-h.p. squirrel cage motor running at 960 r.p.m., production is at the rate of 60 per minute.

Several interesting power hammers are exhibited by B. and S. Massey Ltd. One a 5-cwt. pneumatic power hammer is designed to give the maximum amount of clear space above and around the palletts. The trip will hold up at any point in the stroke, rising smoothly without vibrations, and will also hold down to grip work between the palletts. In addition to a 5-cwt. drop stamp, this firm also exhibit a 200-ton motor driven trimming press of the tie-bolt type, together with a variety of smaller machines.

New Shrinking Bath.

The I.C.I. exhibits include a shrinking bath adapted for use with "Drikold." It is the result of lengthy research into the possibilities of the use of "Drikold" in the engineering and machine tool industries. This exhibit is a simple and efficient apparatus which has already found application in practice. The production of solid CO_2 on a commercial scale has attracted the attention of engineers to the possibility of utilising the extremely low temperature of the material for the production of shrink fits. For this purpose the normal procedure of expanding the outer member of two parts to be assembled is reversed. The inner member is cooled and contracted by utilising the low temperature of solid CO_2 and after assembly is allowed to expand as it heats up to atmospheric temperature.

The apparatus has been successfully employed in a variety of engineering uses, including such diverse applications as the fitting of cylinder liners to internal combustion and other engines and to pump barrels, the fitting of bushes in machine tool manufacture, the assembly of ball races on spindles and in housings, the assembly of large cast iron couplings on shafts and of cast iron and steel components in aluminium castings.

Degreasing Plant.

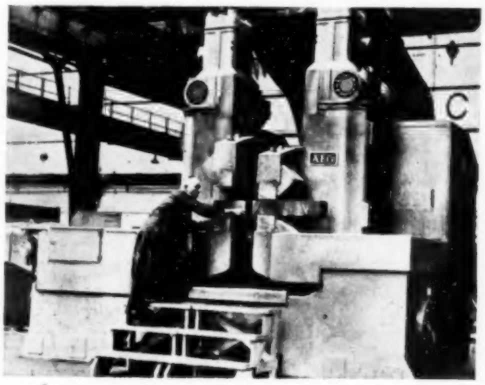
Four models of I.C.I. metal degreasing plant, which employs trichlorethylene, the most powerful known grease solvent, are exhibited. These machines are the proved instruments of a process which is being successfully applied to plating, polishing, enamelling, rust-proofing and all metal finishing processes; to all classes of repair, renovation and maintenance work; in the light metal industries; in foundries and the heavy metal industries; and to garage, service station and motor repair work. Practical demonstrations are given. In addition to standard models, special plants are being produced every day to meet special requirements, and visitors to the Exhibition are invited to discuss metal cleaning problems with the technical representatives on the stand.

Recent Developments in Tools and Equipment

Automatic Flash Butt Welder.

By A. E. CROSKELL, M.I.W.E.

THE accompanying illustration shows what is claimed to be the largest universal, fully automatic flash butt welder yet made, which has recently been completed by the A.E.G., for welding large sections. It can be used for various purposes, such as the manufacture of heavy anchor links, welding large pipes to flanges, etc.



Universal automatic flash butt welder, claimed to be the largest yet made.

The increasing use of alloyed steel such as nickel and chrome called for an automatic control that would ensure the weld being made at the moment when the correct upset temperature of the faces to be welded was obtained, otherwise, a burnt or frozen joint might result. Both types of failure are well known in resistance welders employing a cam or hydraulically-operated burn-off and upset, where the platen is moved forward at a certain definite speed and the upset made at a predetermined moment, neither of which can be altered during the welding process should the section freeze, or in other words, be at too low a temperature for reliable upset.

It was realised some years ago that these troubles were likely to discredit the process of butt welding, which brief title covers the process of flash butt welding, as the older or slow method of butt welding without flashing is rarely used nowadays, and so an automatic welder was designed which relied for its control on the temperature of the weld. The machine illustrated is designed to weld an area of 40 sq. ins.

It has been found that the automatic control adopted makes a considerably smaller peak load call on the line, for the stock is preheated before flashing takes place, and thus the rush of current is much reduced in comparison with the heavy demand of a cam or hydraulically-operated machine, which bangs the faces of the stock together, and proceeds with the burn-off, irrespective of the temperature at the faces of the stock at the commencement of the flashing process, thus the intermittent rating of the transformer is only 800 kva., whilst it is designed to give a continuous output of 400 kva., to weld the maximum area of 40 sq. in. in $16\frac{1}{2}$ min., using 47 B.O.T. units of electricity in the process.

Automatic butt welders are sometimes single-purpose machines for mass production and therefore there is no need to alter the burn-off and upset pressure, but more often than not they are required for a variety of purposes to weld stock of different area and varying section demanding adjustable burn-off and upset. The machine described is universal, inasmuch as both the upset pressure and burn-off can be adjusted in a few moments, without any alteration of gear-wheels or cams, by simply turning a pointer. For instance, the maximum clamping pressure is 70 tons, and the maximum upset 50 tons, both being adjustable for sections down to 4 sq. in., which is the smallest area that can be conveniently handled on so large a machine.

The rating adopted on these machines is based on the maximum demands of the user, which in this case was to weld 40 sq. in. about three times an hour where the metal lost in burn-off or flashing is $2\frac{3}{16}$ in. The machine will weld 20 sq. in. 12 times an hour, consuming 9·2 kwh. for each weld, burning off $1\frac{3}{4}$ in.

The illustration does not show the various automatic controls, which are mounted in an enclosed switch cubicle entirely separate from the machine and protected from flash, as is the transformer, by a special arrangement of its position and design of the platen.

The designers have found from many years of experience that the most satisfactory operation results from an all-electric welder, and so the clamps, as well as the burn-off and upset are operated by three-phase built-in motors, whose torque of course, responds instantaneously to the load. Repetition work calls for very fine limits, consequently, although it weighs 40 tons, the machine is designed as a precision one, special arrangements having been paid to the guide of the platen to cope with the heavy upset pressure of 50 tons, this running in bushes which can very easily be removed and adjusted to take up wear.

A Scientifically Designed Bunsen Burner, Adjustable Jet and Increased Heating Efficiency,

ALTHOUGH the Bunsen burner is probably the most indispensable single item of scientific research equipment, little recent scientific investigation so far appears to have been made as to its design or manufacture. Indeed, burners as generally used remain substantially unaltered since their introduction nearly a century ago. The appearance of an entirely new type of burner is therefore a matter of interest to all laboratory workers or persons interested in scientific equipment. The new burner has been designed and produced by Messrs. Amal, Ltd., of Birmingham.

New scientifically designed Bunsen burner with valuable features.

Scientific workers, especially those engaged on critical work of any kind, involving the careful control of heating, will recognise the inconvenience caused by a ragged flame (due to a faultily constructed or badly centralised jet), and by the fact that existing types of burner, being at the mercy of fluctuations in the gas supply, are always liable to "strike back" and burn at the jet. The usual adjustable sleeve type of air control, besides being insensitive, has an inevitable tendency towards incorrect adjustment, and anything in the nature of a small controllable flame can only be obtained by the common practice of fixing an adjustable screw-clip to the flex. This new burner is designed to eliminate these objectionable features.

Careful attention has been given to the correct burner proportions necessary for maximum combustion efficiency, and generally speaking the new burner combines the outstanding features of both the Meker and the original Bunsen types. The accompanying illustration shows the burner head removed, revealing the adjustable jet, which is perhaps its most interesting feature. The orifice has been carefully placed so that the gas flow is concentric with the air tube, and contains a needle valve, which is capable of almost vernier adjustment by the external screw to maintain the maximum gas velocity according to the volume of gas consumed and the pressure available. There is thus no need for an air regulator, the taper needle (the tip of which is shown in its extreme uppermost position in the ejector) being sufficient to give an accurately controllable flame.

The burner is designed on the venturi principle, which serves the double purpose of retarding the point at which the flame will flash back on to the ejector, and of increasing the velocity of the gas flow, so enabling it to suck in more air through the seven holes at the base. The flame can thus be turned down almost to invisibility by the needle valve without flashing back, and at the same time can be relied upon to give exceptional heating efficiency when full out. The combustion head is perforated with a large number of small holes, so that the flame consists of a cluster of perfectly aerated small cones, which must have an obvious heating advantage over a single aerated flame. This arrangement must also result in more economical combustion than is possible with a detachable rose head, which may, or may not, have been designed to suit the proportions of the burner.

The burner illustrated is $5\frac{1}{2}$ in. in height, with a head of 1 in. diameter. (A slightly larger size, 7 in. in height, with a $1\frac{1}{2}$-in. diameter head, is also manufactured). It has an effective consumption range of 1·3 to 14 cub. ft. of gas at 3 in. pressure, sp. gr. 0·476; a range which testifies to the nicety of control possible with this burner. Another admirable feature is the insulated hooked metal holder. Everyone knows how hot the base of a burner becomes, especially when working under gauze, and a device which enables it to be comfortably removed or held is to be welcomed.

The burner is obtainable at the low price of 12s. 6d., and it is of interest to note that Amal, Ltd., also make burners of identical design, but mounted on a hexagon brass base with $\frac{1}{4}$-in. gas male thread, for use in units or clusters for furnaces, boilers, ovens, etc. These are supplied with interchangeable calibrated jets, and in two sizes with effective consumption ranges of 5—14 and 9—36 cub. ft., respectively.

Tapered Roller Bearings.

A CHANGE-OVER from plain to tapered roller bearings has resulted in a marked increase in output at the works of Messrs. Edelstahlwerk, of Saarbrucken, in the Saar. These bearings were fitted to a 2-high strip mill that runs at 375 r.p.m., and is reputed to be the fastest mill on the Continent. The firm states that it is now able to roll $13\frac{1}{2}$ tons of metal an hour, compared with 7 tons before.

Programme of Institute of Metals.

THE Institute of Metals and its local sections have planned a very full programme for the coming session. There will be three general meetings of the Institute—in March, May, and September, respectively,—at each of which a number of important metallurgical communications will be presented for discussion.

At the May meeting Professor W. R. Bragg, F.R.S., will deliver the 25th Annual May Lecture. The Annual Autumn Meeting will be held in Newcastle-on-Tyne.

In addition to the meetings of the parent organisation, there will be held monthly throughout the coming session meetings of the Institute's six local sections, which are located, respectively, in Birmingham, Glasgow, London, Newcastle-on-Tyne, Sheffield, and Swansea. Before these sections there will be read more than 40 papers, whilst in addition there will be arranged visits to works, a supper-dance, and other social and technical activities.

The programmes of each section are primarily designed to appeal to persons engaged in the local industries; thus, in Birmingham papers will be read on "The Production of Brass Ingots" and "The Rarer Metals—Gold, Silver, and Platinum" (as used in the local jewellery trades).

Membership of the sections is open free to all members of the Institute of Metals, and visitors are invited to attend the meetings, particulars of which can be obtained from the Secretary, Mr. G. Shaw Scott, M.Sc., 36, Victoria Street, London, S.W. 1.

A Rapid Test of Thickness of Tin Coatings on Steel.

The International Tin Research and Development Council, has issued as Technical Publication, Series A, No. 12, a reprint of a paper by Dr. S. G. Clarke, which describes a new rapid method of determining the thickness of a tin coating on steel. The procedure is simple; the tin is dissolved from a known area by a cold solution of hydrochloric acid and antimony chloride, and its amount is determined by the loss of weight of the specimen. The basis metal is unattacked, but a small correction has to be applied to allow for the layer of tin-iron alloy. In addition to brevity, the method has the advantage that the thickness of tin on a given portion of the surface can be determined, by protecting the remainder with a coating of cellulose varnish. Copies of this paper may be obtained on application to the International Tin Research and Development Council, Manfield House, 378, Strand, W.C. 2.

Geared Steam Turbine Installations for Tramp Steamers.

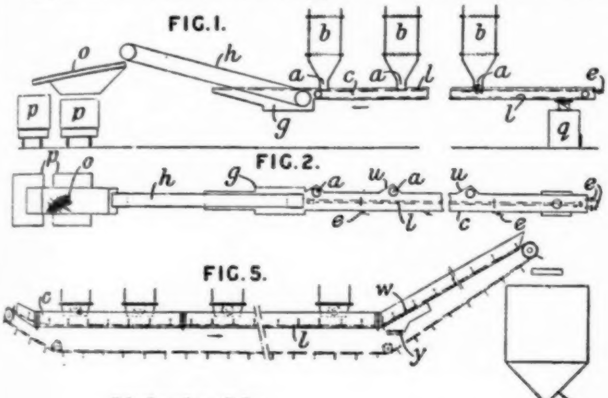
THE rotating screw propeller is the best instrument so far evolved for the propulsion of a large ship through the water, said Mr. S. S. Cook, at a recent meeting of the Institute of Marine Engineers, and the problem of ship propulsion is the problem of imparting rotary motion to a screw propeller in the most efficient and reliable manner, efficiency and reliability being both understood in their broadest significance. A uniform rotary motion being required for the propeller, an engine of the purely rotary type, like the steam turbine appears to be the most appropriate for driving it. Absence of propeller racing makes the turbine-driven ship steadier in a heavy sea. Other practical advantages attaching to uniform rotary drive are mentioned. The geared steam turbine entered the field of cargo boat propulsion with the re-engining of the S.S. *Vespasian*, with engines of this type in 1910, and a large number of vessels have been so equipped since that time, not only for cargo boats, but for vessels of all classes. An installation of geared turbines recently specially designed for cargo boats, making a compact unit with its auxiliaries and simplifying erection and overhaul, is described, and results are given of steam consumption tests carried out with such a set erected at Turbinia Works.

Some Recent Inventions.

The date given at the end of an abridgment is the date of the acceptance of the complete Specification. Copies of Specifications may be obtained at the Patent Office, Sale Branch, 25, Southampton Buildings, London, W.C. 2, at 1/- each.

Discharging Vertical Retorts.

VARIOUS methods have been developed to facilitate the removal of coke from retorts. A recently developed device embraces apparatus for quenching and conveying away coke discharged from vertical retorts B, Fig. 1, of the kind comprising a trough *c* supplied with water at *e* and fitted with an endless conveyor *l*, in which the retort mouthpieces *a*, which are sealed in the water, deliver into lateral pockets *u*, Fig. 2, in order that eddies may be formed in the water stream to assist the movement of the coke away from the mouthpieces into the line of the conveyor. The coke carried along by the upper run of the conveyor *l* is delivered to a sump *g* from which it is raised by a conveyor *h* to a screen *o* by which it is graded and loaded into trucks *p*. The heavier material which sinks in the water is carried in the opposite direction by the lower



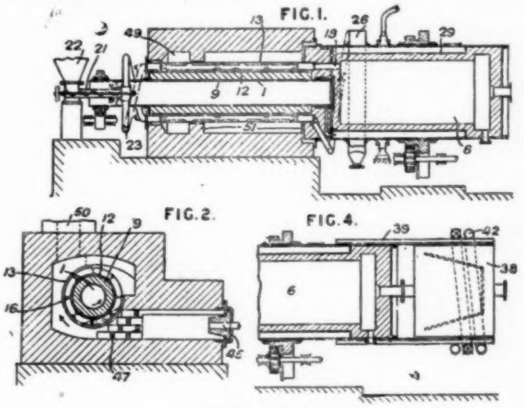
Discharging Coke.

run of the conveyor *l* and delivered to a container *q*. In the modification shown in Fig. 5, in which retorts of elliptical section discharge into similarly shaped lateral pockets in the trough *c*, the lighter and heavier particles are carried away together by the upper run of the conveyor *l*, separation being effected by a screen *w* through which the heavier particles fall on to a transverse discharge conveyor *y*.

403,623. W. B. McLUSKY, Heath Lodge, Skircoat Green Road, Halifax, Yorkshire.

Distilling Zinc.

In a recent development zinc, cadmium, mercury, and other volatile metals are distilled in an annular muffle which is rotated by means of a bearing-shaft within a stationary furnace chamber, the charge being fed continuously and the residue and distillation gases being discharged with exclusion of air. In the apparatus shown the muffle comprises inner and outer shells 12, 13, preferably of nickel or silicon chromium-iron alloy, carried by the hollow shaft 1 around which is an insulating layer 9. Between the two shells are stay members or partitions 16, which completely or partially divide the annular charge space into a number of compartments, and which may be offset relatively to one another to assist in conveying the charge. Feeding is effected from a hopper 22 by a worm 21 through thin copper helical tubes 23, and discharge of the solid residue is similarly effected into a chamber 26, entrance of air being prevented by alternately operated closures. The gaseous products pass through openings 18 into a condenser 6, either fixed, or rotating with the muffle, and provided with an air-cooling jacket 29. Heating is effected by a burner 45, Fig. 2, delivering on to actinolite brickwork 47, the combustion chamber being so situated that the gases impinge first on the part of the muffle against which the charge is heaped. After passing round the muffle in the main heating zone 51, the gases pass laterally to the preheating zone 49, and thence to the chimney 50. The muffle may be heated by electrical resistances. The gases from the main condenser 6 may pass to an auxiliary condenser



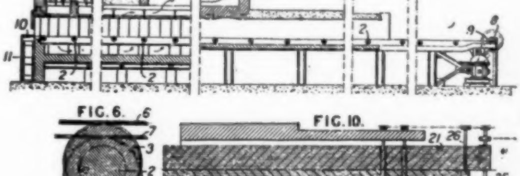
Distilling Zinc.

38, Fig. 4, supported by angle irons 39, and having a valve-controlled discharge spiral 42 for the condensed metal. In a modification (Fig. 5, not shown), the auxiliary condenser is stationary. The main condenser may be formed with open-ended cross tubes to increase the condensation surface, and to promote cooling. In a modified construction, Fig. 3 (not shown), the annular muffle is in the form of a tube wound helically around the insulating layer 9 on the shaft 1.

409,863. KRUPP GRUSONWERK AKT.-GES., Buckau, Magdeburg, Germany.

Conveying Furnace Charges.

The general desire in modern furnaces is to facilitate automatic operation, and a recent development of this kind concerns a continuous furnace, designed particularly for heating small metal articles. It is fitted with a step-by-step conveyer comprising two groups of narrow bars or cables, 6, 7 supported on eccentrics 3, 4 displaced by 180° from each other on the actuating shafts 2, the bars or cables projecting beyond the ends of the furnace and being connected at the inlet end, to the fixed framework 11 through spring 10 which prevent sagging and permit free expansion and contraction. At the discharge end, the bars or cables are connected to straps 9, which encircle mutually displaced eccentrics mounted on a motor-driven shaft 8, the latter also serving to drive the shafts 2 through an endless chain and pinions on one end of the



Conveying furnace charges.

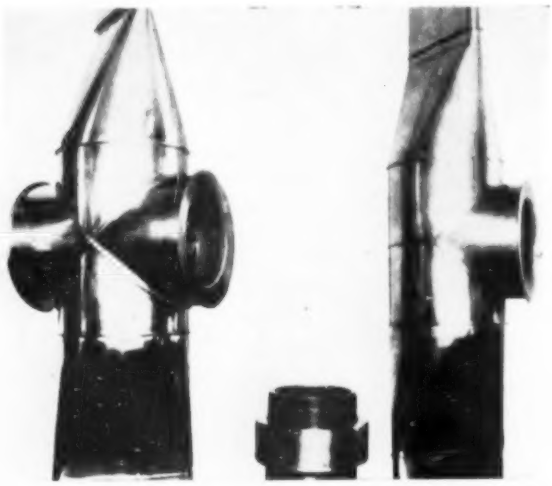
shafts. Fig. 10 shows a modification in which the conveyer is divided into two side-by-side sections 21, 22 operated from separate shafts 25, 26, which may be driven in the same or opposite directions. In the first case, the conveyer operates as in Fig. 1, while, in the second case, articles fed in at the right-hand end of the furnace are carried to the opposite end by section 22, and then transferred to section 21 which returns them to the charging point. In a further construction, the conveyer is divided into three independently-operable sections.

410,353. FOURMENT ET LADUREE, 8, Rue de la Bienfaisance, Paris.

WELDING TANTALUM SHEETS.

THE metal tantalum possesses characteristics which make it especially valuable in the manufacture of all types of laboratory accessories. It is not tarnished by air or attacked by acids, except hydrochloric. In tensile strength it is $2\frac{1}{2}$ times stronger than platinum. It combines softness with workability, and has great resistance to wet corrosion. It is noteworthy, therefore, that tantalum sheets, so thin that it takes 200 of them to make an inch, are now being arc welded regularly in the fabrication of chemical equipment.

Tantalum is a rare metallic element found in association with niobium, and little used commercially until recent years. Most of the supply comes from Australia, although it is found in the United States in small qualtities in North Carolina, Colorado, and in the Black Hills of the Dakotas. Sweden, Norway, Greenland, Madagascar and Rhodesia are other localities where it is known to exist.



Parts comprising Tantalum sheets .005 to .025 inch thickness which are being fabricated regularly for chemical equipment by means of arc welding.

Fansteel Products, Inc., Chicago, Illinois, are one of the largest suppliers of tantalum. It is this company which developed and perfected a method for welding this rare metal, thereby increasing its field of usefulness.

Exacting requirements covering the articles fabricated from tantalum have made it necessary to develop a special technique for welding it, and an American company, Fansteel Products, Inc., Chicago, Illinois, have developed and perfected a method for welding this rare metal, thereby increasing its usefulness. Some of the most important factors which must be considered in working with this metal are as follows :—

Tantalum is a very costly metal, and as most of the articles are not standardised, the labour cost is rather high. Spoilage must therefore be reduced to a minimum.

Finished welds must be strong, ductile and both gas- and liquid-tight under pressure and vacuum. Tantalum, however, cannot be deposited from an electrode without so embrittling the welds as to make them unusable ; nor can it be heated in air much above 650° F. without it becoming hard and brittle.

The melting-point of tantalum is above 5100° F.

The method finally adopted consists, first, in forming a straight-angle flange at all edges of the sheets to be arc welded. These flanges are then fitted together and tack welded in a few places to avoid shifting the assembly. The job is then immersed in a tank filled with carbon tetrachloride, so that the edge to be welded is approximately $\frac{1}{4}$ in. below the surface of the liquid.

Immersion in carbon tetrachloride requires higher voltage across the arc than would be needed to weld in air, and at the same time, the thinness of the stock being welded, and the necessity for strict localisation of the heat, demand low-welding current. Hard carbon electrodes $\frac{1}{8}$ in. in size, held in small light electrode holders, are used. The welding current must be of normal polarity.

Stability of the arc and ease of striking it, as well as freedom from blowing are absolutely essential for producing good welds. An open-circuit voltage of 50 which falls to about 25 across the arc usually produces satisfactory welds. Current depends on the thickness of metal, ·005 in. stock requiring only 15 amps. and ·025 in. 60 amps.

Welding is accomplished by melting the edges of the flanges, so that the metal runs together. This must be accomplished quickly, since holding the arc in one spot or striking it more than once in one place, is likely to result in brittle welds. The examples of chemical equipment parts illustrated were welded with equipment manufactured by The Lincoln Electric Company, of Cleveland, and while it will be apparent that special technique and considerable care are essential in arc-welding tantalum, very satisfactory work is being done regularly on both large and small jobs.

Iron and Steel Institute Co-operates with Technical Societies.

Arrangements have been made by the Council of the Iron and Steel Institute and the Councils of various Local Technical Societies for extending the existing arrangements for mutual co-operation between this Institute and the local bodies, of which the following is an outline : The Council of the Iron and Steel Institute has agreed to extend the maximum age of Associate membership from 24 years of age, as previously fixed, to 30 years of age in the case of associate members who are also members of those Local Technical Societies. Associate members of the Iron and Steel Institute are entitled ro receive the *Journal* and other publications of the Institute free of charge, and to enjoy all other facilities extended to members, including the use of the loan library, but they are not entitled to a vote at General Meetings. The subscription is one guinea a year (instead of three guineas for full membership) and the payment of an entrance fee (two guineas in the case of full membership) is waived ; no transfer fee becomes payable on transference to full membership. (This arrangement does not apply to members of Local Societies who are under 30 years of age, but who are already full members of the Iron and Steel Institute.)

The Council of the Iron and Steel Institute has agreed to supply each year to the Local Societies, for presentation and discussion at local meetings, certain papers which have been presented at General Meetings of the Iron and Steel Institute.

It is proposed to hold one or two Joint Meetings each session between members of the Local Societies and members of the Iron and Steel Institute resident in the particular district. It is hoped by these means usefully to extend the existing co-operation between the Iron and Steel Institute and the Local Technical Societies, and particularly to encourage the study of problems connected with the manufacture and metallurgy of iron and steel, especially among the younger members of those societies.

At the moment the following Societies have intimated their willingness to take part in this scheme : Sheffield Society of Engineers and Metallurgists ; Sheffield Metallurgical Association ; The Lincolnshire Iron and Steel Institute ; The Staffordshire Iron and Steel Institute ; West of Scotland Iron and Steel Institute ; Cleveland Institution of Engineers ; and Manchester Metallurgical Society (subject to confirmation at their next General Meeting).

The Secretary of the Iron and Steel Institute, 28, Victoria Street, London, S.W. 1, or the Secretaries of the Local Technical Societies, will be pleased to supply further information on request.

A circular saw for cutting hot metal in rolling mills has been developed by a Soviet worker, Mr. Shushkov, at the Stalinsk metallurgical plant. It showed good results when being tested at the experimental workshop of the plant. This circular saw is said to have several advantages over the disc saws. The former can work for a longer period, and its production is double that of foreign makes. Working drawings of the saw are now being prepared and will be sent to the Stalin heavy machinery plant in Kramatorsk for manufacture.

Business Notes and News

New Duty on Wire Articles.

Under an Additional Import Duties Order issued by the Treasury on the recommendation of the Imports Duties Advisory Committee, Customs duties at the rate of $33\frac{1}{3}\%$ *ad valorem* has been imposed on various articles manufactured wholly or mainly of iron or steel wire of any section. The main iron and steel wire manufactures, which are already subject to additional duty, are excluded from the scope of the order, as are also certain other important categories of wire goods, but a varied range of miscellaneous wire articles will become liable to the new duty. As examples of such goods are mentioned jack and mattress chain wire shapes (rings, loops, hooks, dees, and similar small wire articles), articles manufactured wholly or mainly of wire mesh, and stationery and haberdashery articles such as pins and wire paper clips.

The duty on wire has tended, the committee found out, to intensify the Continental competition in the simpler manufactures of wire, with the result that prices have been lowered in many cases to below the actual costs of production in this country. The committee, therefore, consider that the duties on these goods should be brought into closer relationship to the duty on iron and steel wire.

In the case of bifurcated rivets, the increased *ad valorem* rate is coupled with a minimum specific duty of 3d. per 1,000 in order to enable the home manufacturers to secure a more satisfactory share of the large orders for the particular standard size of rivet which constitutes the great bulk of the trade, and on which foreign competition is centred.

Diesel Engine Developments.

A Diesel engine, claimed to represent a marked advance in the design of this type of engine for use in road vehicles, has been demonstrated on the outskirts of London. Known as the Armstrong-Saurer "dual turbulence" oil engine, its manufacturers assert that it has important economic and mechanical advantages over other methods of propulsion. Indeed, it is foreshadowed that at the annual motor show in two years time the first Diesel-engined private car will probably make its appearance.

In aircraft, too, it is suggested that a machine fitted with an engine of this kind should be able to fly from England to Australia with halts at every 4,000 miles instead of at approximately each 2,000 miles. The makers further state that with this latest engine it is possible to propel a vehicle weighing 22 tons gross laden at 10 to 12 miles a gallon of fuel, at a cost of only 5d. a gallon. There is a smoke-free exhaust at 2,000 r.p.m., the thermal efficiency, on which fuel consumption depends, has been improved by $33\frac{1}{3}\%$, and crankcase dilution, it is said, has been entirely overcome.

British Pig Iron Productian.

It is noteworthy that pig iron production is steadily keeping pace with reorganisation within the iron and steel industry. Evidence of progress is shown in recent British blast furnace returns. A year ago 75 furnaces were in blast, but this figure has now increased to 100, which shows a consistent rise since March, 1933, when the total was 65.

In North Wales there are two, Shropshire one, West Cumberland five, and Lancashire six. Three new furnaces are being built—one in West Cumberland and two in Northamptonshire. Twenty-four furnaces are being relined or rebuilt.

Metropolitan-Cammell Carriage.

The Metropolitan-Cammell Carriage and Wagon Company, Limited, the successor to the Metropolitan-Cammell Carriage, Wagon, and Finance Company, Limited, has been incorporated as a private limited company with a nominal share capital of £1,000,308 and £1,500,000 debenture stock. The formation of the new company, it is stated, is the final step in the rationalisation of the rolling-stock interests controlled by Vickers and Cammell Laird. The new company has taken over the works and activities of the old company and will carry on the business under the same management as before. The board consists of Colonel J. B. Neilson (chairman); Mr. W. L. Hichens (deputy chairman); Mr. A. J. Boyd (managing director); Mr. T. L. Taylor; Commander Sir Charles Craven; Mr. W. Howard-Williams; and Mr. Alex. Spencer. The share capital of the new company is held by Vickers, Limited, and Cammell Laird and Co., Ltd.

Locomotives for China.

The Vulcan Foundry, Newton-le-Willows, has secured an order to build 16 steam locomotives and tenders for the Canton and Hankow Railway, China, to the order of the Chinese Purchasing Commission. It is understood that the locomotives will be of an entirely new design and of the 4-8-4 type with huge 4-4 tenders.

This type is expected to develop into one of the standard types of Chinese engines. They will be the heaviest non-articulate locomotives for the Far East and will have exceptionally large boilers. Each engine will weigh approximately 111 tons and the tenders 56 tons.

Royal Aeronautical Society Awards.

Messrs. C. W. A. Scott and T. C. Black, as a direct result of their success in the England-Melbourne race, have been awarded the British silver medal for aeronautics, by the Royal Aeronautical Society. The British gold and silver medals for aeronautics were founded in 1933, following a request from Lord Amulree, when Secretary of the State for Air, that the Royal Aeronautical Society should give some award for outstanding achievement in aviation leading to advancement in aeronautical science. A permanent committee was formed to consider the awards of the medals consisting of six members of the Royal Aeronautical Society, the chairman of the Royal Aero Club and the Chairman of the Air League of the British Empire.

The design of the gold medal incorporates a portrait of Sir George Cayley and his first model aeroplane of 1804, and the design of the silver medal shows the Henson and Stringfellow models, the first power-driven model to fly in 1848.

Industrial Gas Development.

The new Industrial Demonstration Laboratory and Showrooms of the Liverpool Gas Company were formally opened last Tuesday (October 16) by Dr. Leslie Burgin, M.P., Parliamentary Secretary to the Board of Trade.

These are a part of the national Scheme of Industrial Demonstration Centres, established by the gas industry, for the two-fold purpose of assisting industrialists in their heat problems and co-ordinating research in gas apparatus for industrial uses of all kinds.

New Trade Openings and the Leipzig Fair.

The Anglo-German Trade Agreement just concluded opens up a good opportunity to develop and expand a profitable trade with Germany. It is, however, essential for the success of the agreement that a brisk exchange of goods should take place between the two countries, as the volume of German imports is directly dependent on the volume of her exports.

A great opportunity for the British supplier to expand his market, not only in Germany, but throughout the world, and for the buyer to pick up new and effective selling lines, is offered by the Leipzig Spring Fair, March 3 to 10, 1935, which is visited regularly by over 25,000 buyers from European countries and overseas, as well as 120,000 from Germany, and where about 7,000 manufacturers from all parts of the world offer their goods.

The Leipzig Fair, which, by the way, maintains a permanent office in London, therefore offers every facility to the trade of both countries to compare each other's productive capacity and establish new business connections, which is in the best interests of our commercial relations and will help to make a success of the new Trade Agreement.

Clyde Shipbuilding Revival.

About 30,000 tons of shipping was placed with Clyde shipbuilding firms during October, representing about 10 vessels, and orders are pending for at least six more vessels. During the last month six vessels were launched, aggregating 35,635 tons, and bringing the output for the river for the year to date to 204,261 tons—a productivity far and above any other shipbuilding centre in the world.

Already this year's output total exceeds those of 1932 and 1933, and there is every indication that the Clyde will pass the quarter-million mark before the end of the year. With the exception of September, when the liner Queen Mary was launched, October has been the most productive month of the year.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£46	10	0
Chinese		41	0	0
Crude			—	

BRASS.

Solid Drawn Tubes	lb.	8¾d.
Brazed Tubes	,,	10¾d.
Rods Drawn	,,	8¼d.
Wire	,,	7⅛d
*Extruded Brass Bars	,,	3⅞d.

COPPER.

Standard Cash		£27	12	0
Electrolytic		30	10	0
Best Selected		29	15	0
Tough		29	5	0
Sheets		58	0	0
Wire Bars		30	15	0
Ingot Bars		30	15	0
Solid Drawn Tubes	lb.	9¼d.		
Brazed Tubes	,,	9¼d.		

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	3	3
‡Ferro Tungsten	,,	0	3	0
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2-4% Carbon, scale 11/- per unit	ton	31	0	0
NOMINAL: 4-6% Carbon, scale 7/- per unit	,,	23	0	0
NOMINAL: 6-8% Carbon, scale 7/- per unit	,,	22	0	0
NOMINAL: 8-10% Carbon, scale 7/- per unit	,,	22	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/0 per unit	,,	34	0	0
Guar. max. 1% Carbon, scale 12/6 per unit	,,	36	10	0
§Guar. max. 0·7% Carbon, scale 15/- per unit	,,	39	2	6
‡Manganese Metal 97-98% Mn.	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§ Ferro-Vanadium 25-50%	,,	0	12	8
§ Spiegel, 18-20%	ton	7	10	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	6	5	0
20/30% basis 25%, scale 3/6 per unit	,,	8	10	0
45/50% basis 45%, scale 5/- per unit	,,	11	17	6
70/80% basis 75%, scale 7/- per unit	,,	18	10	0
90/95% basis 90%, scale 10/- per unit	,,	28	17	6
§ Silico Manganese 65/75% Mn., basis 65% Mn.	,,	14	0	0
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20-25%	ton	15	6	0
§ Ferro-Molybdenum, Molyte	lb.	0	5	6
§ Calcium Molybdate	,,	0	5	4

FUELS.

Foundry Coke—				
S. Wales	—	1	5	0
Scotland	—	1	8	0
Durham	1 0 0 to	1	5	0
Furnace Coke—				
Scotland	—	1	5	0
S. Wales	—	1	0	0
Durham	—	0	17	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£52	0	0
*Commercial Ingots		39	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	9
*Cored Bars	,,	0	0	11

LEAD.

Soft Foreign	£10	5	0
English	12	10	0

MANUFACTURED IRON.

Scotland—			
Crown Bars, Best	£10	5	0
N.E. Coast—			
Rivets	10	10	0
Best Bars	10	2	6
Common Bars	9	5	0
Lancashire—			
Crown Bars	9	12	6
Hoops........£10 10 0 to	12	0	0
Midlands—			
Crown Bars	9	12	6
Marked Bars	12	0	0
Unmarked Bars ...... from	7	5	0
Nut and Bolt Bars .... £7 10 0 to	8	0	0
Gas Strip	10	12	6
S. Yorks—			
Best Bars	10	15	0
Hoops ...... £10 10 0 to	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	9d.
*Cored Bars	,,	11d.
†Strip	,,	10d.
†Sheet to 10 W.G.	,,	10½d.
†Wire	,,	11½d
†Rods	,,	10½d.
†Tubes	,,	1/4
†Castings	,,	1/1½

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	11	0
Foundry No. 1	3	12	6
,, No. 3	3	10	0
N.E. Coast—			
Hematite No. 1	3	8	0
Foundry No. 1	3	10	0
,, No. 3	3	7	6
,, No. 4	3	6	6
Silicon Iron	3	10	0
Forge	3	6	6
Midlands—			
N. Staffs Forge No. 4	3	7	0
,, Foundry No. 3	3	11	0
Northants—			
Foundry No. 1	3	10	6
Forge No. 4	3	2	6
Foundry No. 3	3	7	6
Derbyshire Forge	3	6	0
,, Foundry No. 1	3	14	0
,, Foundry No. 3	3	11	0
West Coast Hematite	3	7	0
East ,, ,,	3	8	0

SWEDISH CHARCOAL IRON AND STEEL.

Kr. per English ton @ 19·40 to £1 approximately.

Pig Iron Kr. 102				
Billets Kr. 240-290	£13 10 0–	£16	0	0
Wire Rods Kr. 280-320	£15 15 0–	£17	12	6
Rolled Bars (dead soft) Kr. 200-220	£10 12 6–	£11	11	0
Rolled Charcoal Iron Bars Kr. 290		16	0	0

All per English ton. f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£24	0	0
,, Braziery	19	0	0
,, Wire		—	
Brass	16	10	0
Gun Metal	23	0	0
Zinc	9	0	0
Aluminium Cuttings	66	0	0
Lead	10	0	0
Heavy Steel—			
S. Wales	2	14	0
Scotland	2	10	0
Cleveland	2	10	0
Cast Iron—			
Midlands	2	7	6
S. Wales	2	7	0
Cleveland	2	12	0
Steel Turnings—			
Cleveland	1	15	0
Midlands	1	12	6
Cast Iron Borings—			
Cleveland	1	5	0
Scotland	1	17	6

SPELTER.

G.O.B. Official		—	
Hard	£10	10	0
English	13	12	6
India	12	0	0
Re-melted	13	5	0

STEEL.

Ship, Bridge, and Tank Plates			
Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	8	10	0
,, ,, (Marine) ,,		—	
,, ,, (Land), N.E. Coast	8	10	0
,, ,, (Marine) ,,	8	17	6
Angles, Scotland	8	7	6
,, North-East Coast	8	7	6
,, Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	10	0
Light Rails ......£8 10 0 to	8	15	0
Sheffield—			
Siemens Acid Billets	9	2	6
Hard Basic ....£6 17 6 to	7	2	6
Medium Basic..£6 12 6 and	7	0	0
Soft Basic	5	10	0
Hoops..........£9 10 0 to	9	15	0
Manchester			
Hoops..........£9 0 0 to	10	0	0
Scotland, Sheets 24 B.G.	10	10	0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	2/-
Finished Bars 18% Tungsten	,,	2/9
Extras		
Round and Squares, ½ in. to ¼ in.	,,	3d.
Under ¼ in. to $\frac{3}{16}$ in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ⅜ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£228	10	0
English	228	10	0
Australian		—	
Eastern	229	5	0
Tin Plates I.C. 20 × 14 box	18/2		

ZINC.

English Sheets	£23	10	0
Rods	27	0	0
Battery Plates		—	
Boiler Plates		—	

* McKechnie Brothers, Ltd., quoted Nov. 10. † C. Clifford & Son, Ltd., quoted Nov. 10. ‡ Murex Limited, quoted Nov. 10

Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.

§ Prices quoted Nov. 10, ex warehouse.